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UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH ADMINISTRATION
OFFICE OF EXPERIMENT STATIONS

REPORT ON

THE AGRICULTURAL EXPERIMENT

STATIONS, 1947

Issued January 1948



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FEDERAL EXPERIMENT STATION IN PUERTO RICO (P. O., MAYAGUEZ)

Kenneth A. Bartlett, *Director*

REPORT ON THE AGRICULTURAL EXPERIMENT STATIONS, 1947[1]

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MILESTONES IN EXPERIMENT STATION RESEARCH

During 1947 the world faced postwar shortages of food, feeds, fiber, and other important products of the farm that were in many respects the worst yet known. Last winter's extreme cold, the spring floods, and the widespread heat and drought of the past summer in major producing areas of the world reduced yields and to some extent jeopardized future prospects for many strategic products of argiculture. Farmers of the United States were called upon during the year to help feed multitudes of people outside the borders of this country, and particularly in war-devastated lands. In meeting this challenge they made as great and continued an effort as at any time during the war. Acreage goals were reached for most major food, feed, and fiber crops, but frequently at the sacrifice of good crop rotations and other management practices essential to soil building and conservation and to continued maintenance of the necessary high levels of productive capacity. A similar situation is faced in the coming year.

Research workers at the State experiment stations were therefore again called upon to find out as promptly as possible how unprecedented production might be accomplished without materially increasing acreages and at the same time with minimum damage to productive resources. Reasons underlying this course were the scarcity of additional good farm land for expanded acreages of major crops

[1] Submitted in accordance with the requirement that the Secretary of Agriculture shall report to Congress on the work and expenditures of the State agricultural experiment stations established under the Hatch Act of 1887 and supplementary legislation. The period covered is the fiscal year ended June 30, 1947.

and the probable economic futility of attempting high production on land that was poor or ill-adapted to the purpose. The backlog of scientific findings from research over the years provided much of the knowledge making possible the vast production of the wartime years and current research added materially to the fund of information essential to continuation of such productiveness. Research workers know, however, that energy and matter can be neither created nor destroyed, but can be dissipated. Whenever, for example, the yields of a crop plant are increased by an improved variety the producing machine is worn out that much faster, and the soil, water, essential nutrients, and other elements entering into such increased yields must be compensated for or the producing machine itself will eventually break down.

During the year experiment station research workers were confronted with serious problems in the continuation of high yields of both plant and animal products while at the same time maintaining essential physical and biological resources. In this connection need for the establishment of fundamental principles underlying all aspects of agricultural production was recognized by them as one of the major factors limiting progress in meeting these problems. In fact, the agricultural production situation emphasized as never before that fundamental research underlying all agricultural production can never be discontinued or even curtailed in small degree without incurring the risk of ultimate disaster. Much of the research of the experiment stations during the year therefore emphasized such objectives.

In the fiscal year 1946–47, $7,206,208 of Federal-grant funds was appropriated under the authorizations of the Hatch, Adams, Purnell, and supplementary acts for expenditure by the stations during that period. These funds, together with supplementary moneys from State sources, were used for the support of investigational work on 3,341 specific lines of research in fields authorized by the respective acts. During the year 405 new or revised lines of research were entered into. Furthermore, the usual turn-over in research took place, involving approximately 14 percent of the total number of active projects. In addition to the Federal-grant funds, the stations expended $27,669,999 from non-Federal sources, including State appropriations for the complete support of more than 4,000 non-Federal lines of research and the partial support of the Federal-grant investigations. Transformation of the research programs of the stations from a wartime status was practically completed in the course of the year. The return of staff members from military service helped to restore personnel to something like normal.

With the passage by Congress of the Research and Marketing Act of 1946, authorizing among other things expanded State and Federal cooperation in research on problems of regional and national importance, experiment station technical workers devoted considerable time during the year to the development of tentative programs for coordinated research on a wide range of farm problems difficult to deal with on an individual State basis, including emphasis particularly on the marketing of agricultural products.

More specifically, widespread attention was given during the year to improvements in soil management and maintenance and in the general farm economy, including better rural housing, labor-efficiency

problems, and the development of better labor-saving machinery for handling farm crops and for protecting plants and livestock against the many diseases and pests which attack them. Much effort was devoted to expediting progress on scientific feeding and breeding of plants, livestock, and poultry for higher yields and more effective resistance to diseases, insects, and other parasites and for better adaptation to differing soil and climatic conditions. Further trials with new and highly effective synthetic chemicals developed for use as insecticides and fungicides were also stressed in order to determine more fully their values and limitations for specific purposes and under conditions prevailing in the various types of farming areas of the country.

The importance of good nutrition in maintaining the well-being of the people prompted continuance and extension of food and nutritional investigations. These were concerned, on the one hand, with furthering our knowledge of what nutrients the body needs, and, on the other hand, with making the most of our food supply by proper selection and by conservation of nutrients. In particular, researches were continued to determine how the nutritive values of foods are affected by various factors operating in the course of production, marketing, processing, and preparation.

Productive agricultural research is a matter of progressive evolvement, all segments of which serve as stepping stones to further logical inquiry and also yield useful results along the way. In fact, most agricultural research progressively contributes useful information almost from the beginning as well as during the life of the investigation and does not depend solely on the completion of the entire program of work before the farmer receives some benefit.

This is illustrated by the fact that many of the items reported upon under individual research achievements have appeared as separate segments of research over a period of years in previous reports on the agricultural experiment stations.

Because of this the concluding phases of many research studies represent more of a bringing together of accumulated findings into over-all final answers than a presentation of any specific new accomplishment. This report on the work and expenditures of the agricultural experiment stations therefore presents more complete accounts of particular accomplishments of research that also reveal significant facts regarding what is necessarily involved in the initiation, prosecution, and termination of specific lines of research.

IMPROVING THE FARM ECONOMY

Experiment station studies designed to improve the farm economy, reported upon or revised for purposes of better orientation, included projects dealing with farm organization, operation, and management, agricultural adjustments, farm labor, farm finance, land utilization, and marketing. Of these, by far the greater number were in the fields of farm organization and management. Out of 80 research undertakings dealing with adjustments in farm organization and operation in the States, some 20 were revised or summarized for publication in order that they might better serve present and prospective peacetime requirements.

As a background to an appreciation of these changes in project procedure, it may be well to explain that for years prior to World War II practically every State experiment station conducted research in farm management, including all important types of farming, designed to reduce to a minimum the physical burdens of farming, simplify the tasks performed by both man and machinery, reduce costs, improve the quality and yield of farm products and, withal, improve the incomes and living conditions of farmers and their families.

Soon after the beginning of the war, these farm-management studies were diverted from their normal courses of effective and remunerative farm operation, with due regard to the principles of soil conservation and utilization, to objectives designed to help in the realization of maximum productive capacity. Annual cooperative State-Federal surveys of the Nation's agricultural resources and total productive capacity were made the basis of adjustments deemed essential to the accomplishment of the war purpose. These surveys of productive capacity also facilitated changes in farm practices made inevitable by extreme shortages of farm labor, machinery, implements, and tools, including parts and repairs, and commercial fertilizers.

Because of food shortages in other parts of the world since the cessation of hostilities, the demand for many farm products has continued strong. The necessity for continuing to produce at maximum capacity, with regard to soil conservation, has created rather urgent needs on the part of farmers and stockmen for new and additional information concerning farm organization, operation, and management; improvements in farm equipment such as farm buildings, machinery, implements, and tools; farm credits, including taxation and income; soil and water conservation and utilization; and land tenure and land values. Farmers operating at such high levels of production also require improvements in marketing facilities and services, such as those provided for in the new Research and Marketing Act which, among other operations, is designed to yield information concerning the processing, packaging, storing, financing, transporting, wholesaling, and retailing of farm products. Furthermore, periodic analyses of the farmers' business relations are needed, including the establishments with which they deal in local buying and selling.

MAKING FARM ADJUSTMENTS

How the farm economics research undertakings that have matured during the past year have tended to supply such needed information is suggested in part by the following examples:

The Iowa station made an 8-year study of war and postwar shifts in farm organization and management necessary to the realization of maximum productive capacity of the farms of the State. The report on this study recommended changes in the pattern of crop and livestock production that might be made in line with the Nation's need for food. Many changes in the nature of the State's farm plant were made during the war. Certain of these have increased the food production capacity of Iowa farms.

Other changes now indicate the necessity for shifting the cropping patterns more toward the conservation of soil resources. Increased mechanization and other forces have brought about a considerable change in farm size in certain areas of the State. The possibility of-

increasing the productivity of farm resources even above the present levels exists in a more efficient use of labor and machinery, in the adoption of improved and profitable practices, and in many sections of the State in a reorganization of farms.

The adjustments recommended were outlined recently in a manuscript entitled "Iowa Agricultural Production in the Postwar Period." The recommendations contained in the reports were used by the Department to aid in establishing production goals. In this manner the study was of direct benefit to the public as well as to the individual farmer in outlining a pattern of production consistent with a maximum food output, in suggesting the limit of crop acreage consistent with conservation of land resources, and in appraising the obstacles that would confront individual operators.

A study made by the New Mexico station of the organization and management practices employed on sheep and cattle ranches provided information helpful to the production of meats and wool needed both during the war and at present. In the 10-year period covered by the study, six press and three research bulletins concerned with war production goals and programs were issued and made available to ranchmen and to State and Federal leaders.

The workers reported that low productivity per unit of land and livestock is a reflection of the overgrazed condition of the range and of the type of forage. This situation is closely allied with an attitude that present profits are more desirable than future ranch incomes. Improved livestock-management practices such as wool improvement, selection of breeding flocks and herds, seasonal breeding, and close culling of aged cows, in conjunction with conservative grazing, aid in maintaining the present level of livestock productivity. Ranch profits during the 5-year period 1938 to 1942 as measured by the return on capital equity invested in the ranch business averaged 5.84 percent for cattle ranches, 6.61 percent for sheep ranches, and 9.57 percent for combination ranches. Individual ranch profits were highly variable from year to year, varying from about 3 to 16 percent for the different types of ranching. On the basis of prewar estimates, the capital equity investment was $1,777 per section of land for cattle ranches, $2,555 for sheep ranches, and $2,118 for combination ranches. Under normal prices for wool and livestock it would require 20 to 30 sections of range land to support a ranch family, meet operating expenses, and pay for land within the productive and active life of the ranch operator without overgrazing and depleting the range resources. The productive value of land for sheep ranching under normal prices for wool and lamb was determined to be about $1,100 a section of land.

The Pennsylvania station in a study to determine the cost of labor in making hay by various methods found that a number of elements combine to give economic significance to the problem. For example, increased emphasis on hay and pasture as a farm crop in Pennsylvania, the difficulties involved in haying, the development of new machines, the shift to tractors and electric power, the relatively high cost of farm labor, and an enhanced farmer interest in the development emphasized the importance of studying this problem scientifically.

Some conclusions drawn from the study were: The monetary cost of harvesting hay ranged from $3.53 per ton when field forage har-

vesters were used to $6.55 when a wire-tie baler was hired. The labor used to move hay from the windrow to the loft was least (1.25 man-hours per ton) when field forage harvesters were used, and greatest (3.18) when hay was pitched on the wagon by hand and unloaded with power forks or slings. The average total investment in haying equipment ranged from $174 when loose hay was loaded by hand to $2,073 when a field forage harvester was used. The smallest average crews—3 men or less— were used with field forage harvesters, tractor buck-rakes, and pitching on by hand. The largest crews—5 men or more—were used with balers.

The Indiana station, in a study of the State's agricultural production, found that significant trends are taking place in farming operations. Many of these are associated with the shift from horsepower to mechanical power. The number of horses decreased from 960,000 in 1917 to 270,000 in 1943. During the same period the number of tractors increased from 3,000 to 95,000. With this change in power coupled with improvement in crop varieties, increased use of commercial fertilizers and lime, and other improvements in technology, the output per man employed on farms has increased greatly. Crop yields are getting higher. Commercial farms are increasing in size. Farm operating units are becoming more complex, an increasing number being made up of several tracts of noncontiguous land. Farmers are now hiring more services that they used to perform for themselves—and this despite the fact that large machines associated with tractors are increasing in numbers. More commercial feeds are being purchased. The acreage of corn used for silage is decreasing. Sanitation practices in livestock production are increasing. Marketing changes are taking place, including a continual shift from cream to whole milk, increased sales of eggs to hatcheries, and increased use of trucks in transportation. Farm home facilities such as electricity, furnaces, and bathrooms are increasing, although the increase was slowed down by war scarcities.

The results of this study were used primarily in policy making, legislation, and teaching rather than in improving the operation of individual farms. The information should be helpful as a guide to the relative importance of various items in the Indiana "agricultural plant," and to the significant trends taking place.

A manuscript was prepared for publication.

In a study of production adjustments to improve farming opportunities in Louisiana, the station in cooperation with the Department and 11 other State experiment stations found that the South, with one-half of the Nation's farm population and one-third of the Nation's cropland, receives only about one-fourth of the total farm income. Both farm and nonfarm per capita incomes are less than in any other region. Cotton accounts for approximately one-third of the total farm income in the Cotton States and now the continued use of U. S. cotton is threatened by foreign-grown cotton and synthetic fibers.

Research on production adjustments that would lead to a more efficiently organized agriculture was considered fundamental to the development of a permanent and prosperous agriculture in the Cotton Belt. Since low per capita incomes are the result of low productivity per worker in agriculture, the first step in achieving an efficient agri-

culture hinges upon a recombination of human and physical resources. The study shows that the acreage of cropland per farm family in Louisiana should be increased from 27 acres to at least 44 in the upland areas; in the Delta areas cropland per family should be doubled—increased from 25 to 50 acres. This will require great shifts in farm population, changes in land use, and development of suitable land, but is necessary to increase the production per worker in agriculture as well as the per capita incomes. That the adjustment problem is involved is generally recognized; the station thus plans to continue work under another research unit on different phases of this population problem in Louisiana until the problem is finally solved.

MECHANIZATION FOR IRRIGATED DESERT LAND

With the shortages and high costs of labor facing stockmen in the western range areas, emphasis has been placed by the Nevada station on investigations to determine the comparative economic efficiency of various mechanical aids to irrigated farm forage production and to select procedures adapted to local conditions that will serve best in final analysis. Cost and labor-efficiency records were obtained on hay-making operations from 37 farmers using balers, 20 using choppers, and 6 using buck rakes. Farmers using buck rakes were found to have the smallest financial investment, whereas those with baler and baler loader had the highest.

The data on labor requirements for hauling and stacking hay by different methods provide especially valuable comparisons. By loading and stacking loose hay by hand one man could handle 3 tons per working day. Where the hay was baled in the field, loaded with a bale loader, then hauled and stacked, 3.9 tons was handled per man per day. Labor efficiency went up to 5.4 tons per man per day when the hay was buck-raked into piles, buck-raked to the stack, and then stacked. Six tons per man per day was handled by chopping hay in the field, then hauling and stacking.

A publication on new machinery and new haymaking methods in western Nevada brings the results of this work to the farmers of the State, to extension staff members, and to workers dealing with similar problems in other regions.

LABOR DISTRIBUTION

During and since the war one of the scarcest elements in agricultural production has been farm labor. Studies of the needs for farm labor in relation to the available supply have been made by most of the State experiment stations. Such studies resulted in many publications used by State and Federal authorities in helping farmers to obtain essential labor and to make such adjustments in crop and livestock systems and the types of farm inplements used as would be necessary to avoid the piling up of labor demands at peak labor periods.

The following examples will indicate something of the nature of these farm-labor studies made for the most part during the war period and some of the uses made of the findings obtained:

The Louisiana station recently reported the results of a study of farm labor needs and requirements of the State by months, seasons, and type of farming areas and the labor available by kind, season,

and area. The data obtained provided a factual basis for using available labor to best advantage in the production of important agricultural products in the State and for indicating deficit areas before the deficit occurred in order that the labor problem in these areas might be solved in time to produce and harvest the needed crops.

It was found that for any particular crop or livestock enterprise the total hours of man-labor needed to produce or maintain a given unit varied widely both as to total requirements and to seasonal variation in different parts of the State. The total labor requirements for cotton produced in Louisiana, for example, varied from a low point of 85 hours an acre in the cut-over pine area of southwestern Louisiana to a high point of 205 hours in the cotton area of the Mississippi Delta. A cotton farmer in the southwestern area, therefore, had to cultivate twice as large an acreage of cotton as a farmer in the Delta region if he were to utilize his labor to the same extent.

These data on labor requirement were widely used by the extension service as a basis for computing the number of men needed in each area and parish each month and for establishing a factual basis on which outside labor, including prisoners of war, could be placed where the need was greatest and on a sound and timely basis. These data were also used by the Selective Service of the State to determine the actual amount of work required on farms where men were applying for deferment.

In a study of farm labor with particular reference to war needs, the Kentucky station obtained data on the supply and the demand in all the important type-of-farming areas of the State. Over a period of about 5 years, this study yielded information for twenty-odd publications used by the State Extension Service in conducting intensive educational campaigns to help farmers plan their crops and livestock systems so as to avoid or minimize labor peaks, to forecast the seasonal labor requirements, and to arrange in advance for the labor needed. In a study of 82 representative central Kentucky farms it was found that 35 percent of the total labor used was spent on livestock. Burley tobacco required nearly three-fourths of the labor used on crops in the State. The peak labor period and the extra day-labor needed in seasons of peak requirements were charted. The sources of extra seasonal workers were the nearby villages and towns, neighborhood farms, and outside areas.

To help the Nation in its war purposes, the North Carolina station made a study of the needs and uses of farm labor and other agricultural resources. The leaders of this study determined how farmers are utilizing these resources in the production of farm products; the amount of labor, material, supplies, and equipment currently needed by farmers to attain production goals; the relationship between the size and type of farm and the amount of labor required to produce essential commodities; and the probable effect of consolidation of farm units on production. They also appraised the degree to which maximum productive capacity could be attained. In the course of the study a number of important publications dealing with the use of agricultural resources in the State were published and employed by State and Federal authorities in setting and attaining production goals. These publications were also used in providing a sound basis for allocating goals to the several types of farming areas of the State.

ECONOMIC USE OF THE LAND

One of the greatest advances made in American agriculture in recent generations has been the effort to conserve the Nation's land resources and make more constructive use of them. Land-economics studies covering a period of years have been made in most of the States. During the past year, several such investigations were reported upon or revised for the attainment of new objectives. Particularly emphasized during the war years was the study of land values and prices. The principal objective of this work was to keep abreast of the trends in prices. By keeping the Nation informed of these trends it was hoped that a land boom, such as followed World War I, might be avoided.

The Indiana station, for example, in a study of farm real estate prices during and after the war reported that the average price per acre in farm-land transfers continued its upward movement until 1946 and that the average price of farm land had more than doubled between 1940 and 1946. The number of farms on which ownership was transferred increased in most counties between 1944 and 1945, but decreased moderately in 1946. The majority of Indiana farms purchased in 1946 were bought for cash. The principal source of credit for buyers who had to borrow to finance their purchases were local lenders—mainly individuals and commercial banks. The proportionate number of loans by insurance companies, however, was higher in 1946 than in 1945. Available evidence indicated that the postwar peak in land prices might be reached in 1947. In 1946 more than half the buyers of farm lands were farmers; most of the owner-operator and tenant purchasers intended to operate the land they had purchased.

The information gathered in this study was made available at regular intervals through the radio, press releases, and regional reports that indicated current developments in the farm real estate market. This information no doubt contributed to the prevention of an unwarranted farm land boom.

In a study of recreational land use development in Brown County, the Indiana station concluded that the use of nonagricultural land for private recreational purposes had proved to be economical from the standpoints both of conservation of resources and of county finances. Moreover, the development has not materially reduced the acreage of agricultural land in the county. In 1939 the total assessed valuation of the land, improvements, and personal property included in the private recreational areas was approximately 10 percent, 20 percent, and 3 percent of the respective total assessed valuations in the county. Taxes payable by the owners of private recreational property in 1940 averaged $20 per cabin and accounted for 10 percent of the total taxes payable in the county. Owners of private recreational property provide a market for labor, building materials, miscellaneous supplies, and farm products.

Continued development in the county will depend to some extent upon the improvement of roads and the availability of electric service in undeveloped areas.

A manuscript on the use of land for private recreational purposes in Brown County, Ind., was submitted for publication as a station bulletin.

In a study of father-and-son business agreements, the Pennsylvania station concluded that transferring the responsibility for operating a

farm from one generation to another is frequently accompanied by a period in which the owner is unable to handle the farm efficiently, and the farm deteriorates. This is often followed by a period during which the owner has little to occupy his time. In addtion, the new operator cannot make permanent plans either for himself or for the farm because of uncertainty about the final disposal of the property. This may continue for many years. It is important to society and to the individuals directly concerned that transfer of ownership and managerial responsibility for farm operation be accomplished with the least possible friction and loss of efficiency. A situation where the transfer could be made with little or no disruption of the farm organization would be ideal. Where father-and-son partnerships were in successful operation the resources and capacities of both were utilized and no period of farm deterioration occurred. Several conditions had to be met, however, in order to create reasonable likelihood of a successful outcome. Chief among these was a business large enough and successful enough to support two families adequately, and with sufficient tolerance so that the farm business could be handled without personal friction.

The Nebraska station in a study of land use planning concluded that 20,949,240 acres in the State are suitable for cultivation, but that not all of the land should be in cultivated crops continuously. In recent years about 20,000,000 acres has been in crops or in tilled fallow. For the State as a whole, it appears that no drastic reduction in the cropland base is needed. A decrease in the acreage of intertilled crops and a material increase in the area kept in grasses and legumes for a part of the time are the principal changes that would result from use of the recommended cropping systems. A regrassing program is needed in some crop-adjustment sections and on many individual farms. This would to some extent decrease the tilled-crop acreage. A cropping program was worked out for each soils area in the State.

The Kansas station reports that research during the past year has determined the relative physical and economic productivity of land types in selected areas of the State. The results will aid farmers in determining how each land type should be used to get the maximum profit. In one area studied (Geary County) 17 percent of the cropland produces low yields that result in approximately $1 per acre loss each year. If this land were in pasture, the profit to the land would exceed $1, or a total gain of more than $2 per acre. If this represents the situation throughout Kansas and if only half the adjustment were feasible (about 30,000,000 acres of cropland at 8.5 percent adjustment), Kansas farmers would increase their profits by more than $5,000,000 annually. This study indicated that about one-third of the land is inaccurately assessed to the extent of 12 percent or more. Improved assessments based on the economic productivity developed by this study would equalize property taxation and reduce tax delinquency; this value cannot be measured in terms of dollars.

The Kansas station also reported that land price trends in that State have been analyzed by counties, by type-of-farming areas, and on a State-wide basis. These data are now available for the period 1910 to 1946. Thus an up-to-date record of land prices has been prepared from which information is available to land purchasers, sellers, lend-

ers, and public officials responsible for the assessment of agricultural real estate for taxation purposes.

A progress report of the Texas station indicates that farm-property transfers moved at a brisk pace during 1946 in the three sample counties studied. Owner-operators bought a higher percentage of farms in 1946 than in 1945, as nonfarmer buying declined. The proportion of cash sales decreased markedly during the year, whereas the use of mortgage credit almost doubled. In Ellis County the average increase in the selling price of land amounted to $5.80 per acre over the 1945 average and in Nacogdoches County prices rose an average of $4.46 per acre. On the other hand, Jones County, which registered an average increase of $13.24 per acre the previous year, experienced a decline of $2.10 per acre from the 1945 high of $51.29 per acre. A comparison of 1946 price increases in Ellis and Nacogdoches Counties with the 4-year (1942–45) average increase of $3.12 and $3.23 per acre, respectively, suggests an acceleration in the upward trend of land prices in these two counties.

Michigan farm-land prices on March 1, 1947, were 119 percent higher than the 1935 to 1939 average, according to the Michigan station. Farm-land prices for the Nation increased 92 percent during this period. Michigan was in the upper quarter in rate of increase. Farm-land prices in the State rose 16 percent in the year ended March 1, 1947, following an average increase of 1 percent a month for the preceding 4 years; present land prices are 26 percent above the previous record high of 1920. Farm-land prices in both Michigan and the country as a whole have increased more sharply in the past 5 years than between 1915 and 1920. The number of farms changing hands has been running about twice the 1925–1939 average.

The farm mortgage debt for the country as a whole declined until the beginning of 1946 and has been rising ever since. Farmers in general are in a more satisfactory financial situation than they have been in a long time. In the six counties studied, cash covering the full purchase price was paid by about 58 percent of the purchasers in 1946, as compared with 76 percent in 1942. The high percentage of cash purchases is in sharp contrast with the situation during and following World War I. Although a high percentage are now paying cash, it should be pointed out that 42 percent gave mortgages in 1946. On these purchases the mortgage indebtedness averaged 55 percent of the current purchase price; this means that the average mortgage given in 1946 was more than the total farm value in 1942. Some individuals have mortgages exceeding 75 percent of the present purchase price. Such a mortgage puts the current purchaser in an exceedingly vulnerable position.

Although farm-land prices have increased more sharply in the past 5 years than between 1915 and 1920, it is thought surprising that they have not risen even more repidly. The ratio of net farm earnings to land prices during the past 5 years has been more than twice as high as during the preceding 30 years. In other words, it has taken fewer bushels of wheat and beans and hundredweights of milk and hogs to pay for the land purchased. The number of farms changing hands has been running about twice the 1925 to 1929 average. The farm mortgage debt for the country as a whole declined until the beginning of 1946 and has been rising ever since. Cash covering the full purchase

price was paid by about 58 percent of the purchasers during 1946 in the six counties studied. This compares with 76 percent in 1942.

The Ohio station reports that during 1946 the farmers of the State established a new high in the total receipts from farm products. Preliminary information on the sale of products raised on Ohio farms would indicate an increase of about $90 million, or 12 percent, over the previous year. This would amount to an increase of about $480 in gross receipts per farm. The higher prices paid for everything purchased by farmers absorbed about half this increase. An excellent crop year, an increased production of dairy products, and higher prices were important elements in bringing about this record high in gross receipts. The total income from dairy products was 30 percent higher than in 1945 and income from the sale of meat animals was up 24 percent.

The Missouri station found that prospective family income from average farms—160 acres in size and located on grade 2 Missouri land—approximates $800 to $825 annually, when prices are around 1931 to 1940 levels. Very little difference is likely to occur between the income to tenants and owner-operators provided interest on investment at 4 percent is considered as an expense. The investment required in order to obtain the income amounts to aproximately $13,450 for owner-operators and $4,900 for tenants. To obtain about $815 income per year the farm operator and his family work approximately 3,100 hours annually, or an average of 60 hours weekly; this is equivalent to a monthly income of $68 per month, or 26 cents per hour. This income includes the value of farm perquisites. If the net income in the areas of second-grade land in Missouri has made an increase comparable with the increase in the average net income of farm operators in the United States as a whole from 1940 to 1944, the probable hourly income of farmers in the area would be approximately 60 to 70 cents per hour.

In a study made by the Kentucky station of a highland area, it was found that most of the farms lie along small branches—narrow creek valleys from which steep hills ascend to sharp crests. The hillsides also furnish meager grazing (averaging 23 acres per farm) consisting usually of wild grass and sometimes a sprinkling of lespedeza and timothy or other tame grasses. On most of the farms corn was the only grain produced. It was used largely as corn meal for the families and as feed for the livestock. The small branch farms—the predominant type in the area—had an average of 5.8 acres of corn per farm, 90 percent of the acreage being on hillsides steeper than 30 percent. Most of the livestock and their products were consumed by the farm family. The livestock and animal products sold consisted chiefly of calves and surplus chickens and eggs.

Of those operating the farms studied, 58 percent were full owners, one-fourth were part owners, and 19 percent were tenants; in addition, one-fourth of the families were croppers. On these farms 57 percent of the operators' dwellings were of boxtype construction, 38 percent were weather-boarded frame, the remaining 5 percent chiefly log houses. The average cash income from sale of farm products on the small branch farms was only $193 and on more than half it was less than $100. The average for all the farms was $202.

About three-fourths of the operators worked for wages away from the home farm at least part of the year, the income from this source averaging $352 for all of them. Earnings of family members other than the operator for work away from home averaged $125 per farm. "Gratuity" incomes of operators and members of their households averaged $54 per farm. The total spendable income earnings of the operator and other members of the family averaged $572 per farm. Half the farm operator families had spendable incomes of less than $400, 29 percent had less than $200, and 36 percent had $600 or more. All the larger incomes were derived principally from nonfarm sources.

FARM FINANCIAL PROBLEMS

With the cost of labor and the things that farmers buy the highest ever, it is well that a majority of the stations have conducted progressive studies in the several aspects of farm finance, including, for example, farm credits, farm taxation, and farm income. Some examples of current research in this field that had advanced to the point of yielding useful results follow:

The Arizona station found that cash income from agriculture in the State was 160 million dollars in 1946. This compared with a cash income of 134 million dollars in 1945 and was nearly twice as high as its average for the 10-year period ended in 1945. Leading among the sources of income for the second year in succession were lettuce, carrots, and other truck crops, with a total cash value of 38 million dollars. The income from cattle and calves was 37 million dollars, as compared with 29 million in 1945.

The largest proportional increase among all crops was the return for cotton lint and cottonseed, the value of the crop being 31 million dollars in 1946, as compared with only 17 million dollars in 1945.

The wage per day without board for farm labor in Arizona was $5.70 in January 1947, as compared with an average January rate of $1.90 for the period 1935 to 1939.

Land under irrigation in Arizona in 1946 comprised 775,000 acres, or about the same as in 1945. A record production of vegetables on 100,000 acres occurred in the year ended July 31, 1946, as compared with 75,000 acres in the previous year and 60,000 acres in the period 1941 to 1943.

Sheep number, including those owned by Indians and non-Indians, have continued to decline in Arizona. Ewes owned by white men probably did not number much over 150,000; the rest of the State's sheep are on Indian reservations.

The extra-white upland cotton grown under irrigation in Arizona, Califronia, New Mexico, and the western Pecos River areas in Texas has become an increasingly important factor in American production.

More than 30 percent of the irrigated land in the State was in alfalfa in 1946.

In a study of farm income the West Virginia station found that apples constitute the most important cash crop in the State, accounting for about 8 percent of the cash farm income from all sources or 30 percent of the cash income from all crops. Commercial apples production is concentrated in the eastern Panhandle of West Virginia, where 85 percent of the commercial apples of the State are grown.

On the 45 orchards selected for intensive study during 1938 to 1941

the following characteristics seem important as an indication of average performance for the period: Average area in bearing apples per orchard, 91.6 acres; average yearly yield, 257 bushels per acre; proportion of all apples packed, 57 percent; gross returns from apples, $17,154 per farm, $188 per acre, $4.21 per tree, and 72 cents per bushel; expenses for apple production, $16,384 per farm, $179 per acre, $4.02 per tree, and 69 cents per bushel. Production items accounted for one-fifth of the total expenses, harvesting for one-third, marketing for nearly one-fifth, and overhead for one-fourth.

Net returns were $791 per farm, $9 per acre, 19 cents per tree, and 3.3 cents per bushel. The total investment were $20,982 per farm, $229 per acre, $5.15 per bearing tree, and 88 cents per bushel. Land in trees accounted for approximately one-fourth this amount, bearing trees for between one-third and two-fifths, and for equipment one-seventh.

The Puerto Rico University station surveyed 347 farms scattered over 54 municipalities during 1939 to 1940. The growers' net worth constituted 80 percent of the total assets. The approximate ratio of current assets to current liabilities was 2.5 to 1. One-third of the 321 full owners and part owners investigated had mortgages outstanding on their farms on June 30, 1940. The Federal Land Bank and Land Bank Commissioner loans were the most important source of long-term credit. This agency granted 53 percent of the mortgages, constituting 59 percent of the total mortgage debt on farms. Ninety-six percent of the farmers in the survey used credit for the production of the crop.

The method used to finance the sugarcane crop was affected by the size of the enterprise and by the geographic location. The large planters ("colonos") financed principally the smaller growers. The Production Credit Association, fertilizer dealers, and commercial banks showed a tendency to deal principally with larger growers. The Emergency Crop and Feed Loan Office and the Production Credit Association were of some importance only in the northern, east-central, and central mountainous areas. The total debt incurred, including personal loans and accounts, amounted to $81 per cuerda (0.97 acre).

The amount advanced to the farmers surveyed for the production of the 1940 sugarcane crop constituted 75 percent of its value and 56 percent of the income from sugarcane, including the Agricultural Adjustment Administration payments. Less than half of the 218 loans analyzed for cost of credit were guaranteed by a written contract. The interest rates charged by lenders ranged from 4 to 9 percent. The policies followed by lenders seem to be the most important factor in determining the cost of credit to growers. In dealings with lenders farmers are handicapped by their low level of education. The methods of granting credit, charging interest, etc., have to be simple so that growers can understand them.

In a study of the income of Ohio farmers by counties, the Ohio station found that a significant development is the increasing importance of soybeans as a source of income. Butterfat sales have decreased, while the sale of fluid milk has increased. Over 70 percent of the State's agricultural income is derived from the sale of livestock and livestock products.

Data presented on crop production and value for 10 southeastern States by the North Carolina station show that a few crops such as cotton, tobacco, and peanuts occupy a relatively small proportion of the total land area and yet produce a disproportionately large share of the farm income. The possibilities and problems encountered in increasing the proportionate amount of income from the acres now in other crops is presented.

TOWARD A MORE EFFICIENT MARKETING OF AGRICULTURAL PRODUCTS

With the enactment of the Research and Marketing Act of 1946, the State experiment stations found it necessary to reorganize their entire marketing programs and revise their objectives in marketing so that future programs might comply more closely with the intent of the new legislation. In some instances, this meant the closing of a number of individual research units that were approaching maturity. In other cases, it was necessary to discontinue some marketing research that was being conducted on a State basis in order to comply with certain provisions of the Act and emphasize marketing research on a regional basis. Another factor responsible for the conclusion of the large number of marketing studies during the current year was the easing of emergency conditions brought about by the war in the fields of packaging, transportation, and storage. A large number of the experiment stations have been engaged in marketing research work to meet emergency conditions. A few examples in this field of endeavor may be mentioned.

The Maryland station in its study of marketing problems arising from the war emergency points out that shortages of labor, rubber, gasoline, containers, and other supplies created new problems in this field. These restrictions required maximum use of facilities available in the marketing process and considerable shifts in the customary methods used. Improvements in marketing facilities helped considerably in moving produce at less cost and with less waste. The study revealed that livestock sales at public auctions increased substantially within a year or so following our entry into World War II; this heavy liquidation was largely owing to labor and equipment shortage, and to farmers and farm laborers entering the armed services. Stocks of both new and used containers for fresh farm produce were substantially reduced by 1942, thereby making necessary various shifts in packaging and special emphasis upon salvaging programs.

Duplications or overlappings in assembling milk for the Baltimore market were serious in the western portion of the milkshed; the mileage traveled by motor vehicles collecting milk in this area was three times the public road mileage, whereas that in the eastern portion of the milkshed equaled only one and one-half times the public road mileage.

Locally grown produce sold at Marsh Market in Baltimore averaged 3.5 sales per load. One-half of the loads were divided among two or more buyers, and nearly 60 percent of the loads were delivered to four or five parts of the city. Narrow streets, lack of rear and front access, and absence of end-gate loading platforms resulted in congestion and excessive labor in handling produce in Camden Market.

Data on trends in livestock sales during the war served as a guide for planning livestock production during the war period. Facts about

the container situation served as a basis for developing a salvaging program and emphasizing the need for better care of containers.

Information collected in the milk-transportation survey was used by the Baltimore Dairy Industries Transportation Committee, in collaboration with the Office of Defense Transportation, in determining a program of action regarding conservation of trucks and materials. Substantial reductions in milk hauling mileage followed.

Facts concerning the delivery of produce in Baltimore City by farmers from Marsh Market and the time consumed in unloading, buying, and loading in Camden Market provided a background for devising methods and facilities for handling fresh produce more quickly and efficiently.

Information obtained from the survey of wholesale produce market facilities in Batlimore was used by the Governor's Commission on the Baltimore wholesale fruit and vegetable markets and by other interested groups in their studies of ways and means of improving the produce marketing facilities in that city.

Seven publications and reports were issued to summarize the results of this study.

The Oklahoma station reports that results obtained in its investigation of milk transportation in the Stillwater area under wartime conditions show that by eliminating duplication in truck routes, a savings of 179 truck-miles per day could be made. Figured at 5 cents per mile, the savings amounted to $3,266 per year. Also, the equivalent to 1,095 ten-hour man-days, or $4,380 figured at $4 per day, could be saved. Possibilities of savings were then about $7,600 per day and would amount to a much higher figure with present high prices and costs. The bulletin prepared on the results of the study was used in extension work. Talks on the results were given to the truckers of the Enid Cooperative Creamery and to the Oklahoma Cooperative Creameries Association. The findings were also discussed at milk producers' meetings held in the Stillwater area of the State.

In the Pacific Northwest, freight rates on livestock are very important and are given a great deal of consideration by producers and marketers alike. Not all western States are surplus meat-producing areas and a considerable volume of livestock, meats, and meat products are shipped from heavy producing areas in the Middle West and some Western States to the Pacific coast for sale and consumption. Because of adequate transportation services the market prices for live animals in the Pacific Northwest should be tied closely with the prices of comparable livestock from other areas. In order to make possible a comparison between such prices the Oregon station conducted a study of transportation rates on livestock and meat products between surplus and deficit producing areas in the western States. On transcontinental shipments the rates of both livestock and livestock products were tabulated.

Competive freight rates from interior points to Pacific coast points were also taken into consideration. Rates on livestock and meat products were compared. Stop-over privileges at important shipping points were noted and routing of shipments with attendant privileges of "trying the market" at intervening points was indicated. The study has been completed and the published account should serve as a handbook on freight rates for livestock and meat products from important

producing centers to principal markets. The completed study on livestock and meat transportation rates is one segment of a general investigation of transportation costs and their effects upon the major agricultural enterprises in Oregon; other segments of the study will be continued and the results released from time to time.

The first regional livestock marketing research undertaking in the Middle West was approved in the spring of 1941. The Illinois station, in reporting the results of their part of the work, dealt with efficiency in the use of trucks, full loads to market and return, truck tire requirements, and county truck surveys to measure the actual conditions and use being made of trucks. Continuation of efficient truck transportation was vital during the war period, and not only to livestock marketing but to other essential agricultural operations as well. With the appearance of the wartime transportation emergency work this study was focused on practical problems in that field. The results of the first release in August 1942 showed that trucks hauling to central markets were being used much more efficiently than those hauling to local markets, that trucks would be able to operate for about 14 months on tires then available, and that farmer cooperation could contribute materially to increased efficiency in truck operations.

A spot study survey of motortrucks in Douglas County issued in November 1942 showed the proportions of truck mileage used in transporting different major agricultural products. The study indicated that 60 percent of on-the-road tires on commercial trucks would be worn out in 12 months. A similar truck survey in Henderson County, released in January 1943, showed that 69 percent of on-the-road commercial trucks would be worn out within 12 months.

A second study of market and return loads by livestock trucks, released in July 1943, indicated that efficiency in the use of these trucks had increased since the 1942 study.

Later surveys disclosed an increasingly critical situation as to use expectancy of trucks then still in service. The Illinois data contributed to a preliminary report on increasing livestock-transportation efficiency put out by the University of Missouri for a regional publication in January 1944.

A third study by the Illinois station of market and return loads by livestock trucks reported that tire replacements would be necessary on one-third of the trucks within 3 months, that recap tires were not proving satisfactory, that synthetic tires were giving about half the mileage of prewar tires, that half the trucks would probably be out of service within the year, and that a significant number of trucks were constantly out of use because of needed repairs or shortages of gasoline, tires, or drivers.

The study indicated that for those trucks still in operation pick-up mileage had been reduced and that the percentage of in-bound full loads had been increased. This work kept truckers, marketing people, and the Office of Defense Transportation informed as to actual conditions in this field and thus assisted them to act more intelligently.

The studies also pointed out that much better service could be obtained from synthetic tires if truckers were furnished reliable information on their proper care and use. The Office of Defense Transportation followed up by issuing such information.

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The Nebraska station reveals that farmers of the State ordinarily secure over 70 percent of their gross income from the sale of livestock and livestock products. Because of this, farmers are directly interested in price differentials for the various grades and weights of livestock. They wish to know the differentials (1) among markets located in the State and important markets outside the State for certain classes and grade and weight groups of livestock of the different species; (2) the differentials among selected classes and grade and weight groups of livestock in the same market, and (3) the influence of day of week, if any, and month of year upon the differentials.

The results of this study showed no relationship between day of week and price of hogs on the market. Lightweight hogs varied less in price than heavy ones. Seasonal changes in price differentials between various weight groups of barrows and gilts were caused primarily by changes in the relative supplies of hogs of different weights. A large proportion of the barrows and gilts marketed in October, November, and December consists of pigs farrowed the previous spring, which are normally of light weight. Hence the price of heavier hogs tends to be high in relation to those of lighter weight. As the season progresses the proportion of lighter weight barrows and gilts decreases and the price of heavier weight hogs then becomes relatively weaker, with the widest differentials prevailing in the summer months. The highest proportion of heavy hogs comes from the western Corn Belt, where the corn supply is relatively large and where transportation charges encourage the shipping of pork rather than corn to eastern markets. Geographically, hog prices were highest in areas of deficit production on the east and west coasts and lowest in the upper Mississippi Valley.

Information on seasonal price differentials among hogs at different weights is helpful in determing when to breed sows and in deciding at what weights to sell. To maximize net returns on his hog enterprise each farmer must also consider his production costs at different seasons of the year and for different weights of hogs. Since there is no one day of the week when prices average higher than on other days, a farmer need not try to market all hogs on Monday as some farmers have preferred to do. Farmers in the western part of the Corn Belt do well to follow prices at more than one market. This is particularly true in the area where there are large purchasers for shipment to the west coast.

At the time the Ohio station began to study the place of the small- and medium-sized slaughtering plant in the marketing of Ohio livestock the slaughtering facilities in the State were limited. Moreover, with the heavy production of hogs during 1944, considerable interest was aroused over the available capacity of processing plants. Additional interest was also manifested in the increased use of food lockers and in the possibilities they offered to small slaughterers. It was learned from the Census of 1940 that there were 158 meat slaughterers in Ohio in 1939; during the last quarter of 1945 the number had increased to 729. The conclusions were that "no doubt this number will decrease as we move into the post-war period but Ohio will probably have considerably more plants than before the war." Certainly, no concern was felt as to slaughtering facilities for regular packing purposes or as to the slaughtering of livestock for the user of food lockers.

The publication, made available to those interested in the slaughtering industry, can serve and give useful information to anyone interested in entering the meat-slaughtering field within the near future. It may also serve as a somewhat sombering influence on those farmers who believe they should get into the meat-packing business.

The Iowa station reports that sales of whole milk from farms in the State increased about 60 percent between 1940 and 1945, while total sales of milk equivalent from farms increased only about 2 percent. A large part of the increase in whole milk sales may be attributed to the growth of skim milk drying in Iowa from 392,000 pounds in 1939 to over 9 million pounds in 1945. This growth was due chiefly to the strong demand for nonfat dry-milk solids by the Government and to the resulting high prices. Prices paid to farmers from 1942 to 1945 were well above the cream-feed value of whole milk and the question was asked, "Are farmers likely to find it profitable to sell whole milk rather than only cream, and will more creameries need to convert to whole milk?"

The results of a study on the economic evaluation of skim-milk drying indicate that for the farmer whose dairy enterprise is a major part of his farm business, skim-milk drying plants are likely to furnish a more profitable market for milk in the long run than the sale of cream only. In 1945, 10 dried skim-milk dairy plants in Iowa showed total direct and indirect costs of handling and drying that ranged from 3.13 to 6.66 cents per pound of skim-milk powder. Volume, fluctuations in monthly production, and the extent to which the plants were diversified proved to be important elements affecting plant costs. The competitive position of Iowa drying plants relative to those in Minnesota, Wisconsin, and the country as a whole appears to be weak because the average volume of Iowa plants is comparatively low, thus making for high costs, and because their past history, high proportion of roller-dried product, newness and probable lack of sales contacts, and lack of unified selling effort make it likely that they must sell a large proportion of their output as animal feed.

The published analyses have helped farmers and creamery operators to make current decisions concerning the disposition of their milk.

When the New Hampshire station initiated a study of the supply and distribution of milk in the State little was known concerning the structure of the milk market or the transportation, collection, and processing of milk for local markets. The milkshed was expanding, and both price and quality of the milk were fluctuating widely. Some form of organization and control of the industry was clearly needed in order to bring stability to the market. Basic data were needed so that leaders in the industry might have a more accurate understanding of the complex problem of production, transportation, and distribution. The effects of different price policies upon the area of supply and the channels of distribution were particularly needed.

After the main studies had been completed, the investigation was continued in order to supply current information to leaders of the dairy industry and to reformulate currently important problems associated with production, transportation, and marketing. Thus, during the war there was a need for special information that could be used by farm leaders and the Office of Defense Transportation in the reorganization of milk trucking. This was done to conserve trucks,

rubber, and gasoline. At other periods information was secured and used concerning the possibility of increasing the supply of milk to prevent undue shortages in local markets. The findings of the study show that milk-transportation costs from farm to creamery of $300,000 a year can be lowered both by reducing the rates when they are above the competitive level and by reorganizing the routes. In the Merrimack Valley milkshed the reorganization of milk trucking from farms to creamery would amount to a saving of approximately $35,000 a year in truck operations.

The following facts were noted in the analysis of markets: A differential in prices of one competing market over another will, if continued for a considerable time, create a desire on the part of some of the producers in the lower-priced market to shift to the higher-priced ones. Factors other than price, however, may be sufficiently potent to delay, offset, or even reverse the action initiated by the price differential. Where the buyers are capable of exercising absolute control over the amount of milk they purchase, price differentials between markets are of secondary importance. Large savings in total truck miles were made by the reorganization of trucking in the Colebrook area of New Hampshire.

This study in cooperation with the New England Research Council has made available a good picture of the structure and price relationships of the complicated milk market. Combined with similar projects in other New England States, it has been used by administrators in working out plans for stabilizing the markets. Detailed information was given to the Office of Defense Transportation showing the location of shippers and truck routes. In most of the milksheds, suggested reorganization plans were included. As a result, the Office of Defense Transportation was able completely to reorganize trucking in New Hampshire and thus to conserve trucks, rubber, and gasoline. The milk industry of this State would have been quite helpless if the trucks had not been conserved to last out the war period. In the Colebrook area a reorganization of the long routes has made it possible for the truck operators to continue services without an upward revision of rates.

Seven publications have been released as a result of this investigation.

A study of the organization, business activities, and problems of cooperatives was undertaken by the Vermont station with the encouragement of the Vermont Cooperative Council. The study had two primary objectives: First, to ascertain the present status of cooperative business organizations in Vermont and their importance to the agriculture of the State; and, second, to analyze the various forms of cooperative business activities in Vermont with respect to purpose and function, organizational and financial structure, membership relations, and record keeping. For the first time a complete up-to-date picture is now available of the position of cooperative business activities in Vermont's economic life.

The record shows that organizations following cooperative business principles have grown in importance until they now represent a significant element in the business activity of the State. Milk accounts for better than two-thirds of the cash farm income of Vermont farmers. More than half of this milk is marketed cooperatively

through plants owned and operated by producers; in addition, the sale of a quarter to a third more is arranged by cooperative marketing associations. Moreover, Vermont farmers buy collectively through their cooperatives 40 percent of the feed and fertilizer used and arrange through them for 12 percent of their long-term and 7 percent of their short-term loans. One out of every five electrified farm homes served from Government-financed cooperative lines and more than one out of every two using a freeze-locker service patronize a cooperatively owned plant.

In the milk-marketing field alone, operating cooperatives did a gross business volume in excess of 31 million dollars during the year. The equity of the Vermont stockholders or members of these cooperative dairy corporations exceeded 3 million dollars or about $380 per member. Materials collected have been used in the 4-H Club program. Summaries of certain essential features have been compiled and made available to the Vermont Cooperative Council for use in its educational activities. Summaries of the cooperative purchasing activities in the gasoline, oil, and farm implement lines were prepared for use by a group discussing cooperative activities in these fields.

Much of the materials has been used for classroom teaching purposes, and the Vermont Cooperative Council plans to assist in obtaining wide distribution of the forthcoming station bulletins reporting these investigations.

As a result of a somewhat similar study the New York (Cornell) station reports that a large number of small cooperative fire insurance companies in the State are operating in rural areas. Wide variations among these companies were known to occur in loss ratios and operating costs; losses and operating costs also varied among geographic areas and between periods of time. This study was undertaken with a view to determining the factors associated with such variations. If these factors are known, it should be possible to reduce losses and costs through greater selectivity of risks and to develop a more equitable rate structure reflecting differences in the risks assumed.

Such a study should prove useful to small mutual fire insurance companies whose members are mostly farmers. This study made public the first facts concerning the incidence of fire and lightning losses on various classes of farm property and the relationship of loss rates to various physical and economic characteristics of farms. As a direct result, one group of companies insuring 50 million dollars' worth of farm property revised its rate schedules to apportion costs more equitably. This procedure reduced insurance costs to many farmers who had been paying the cost of insuring risks more hazardous than their own. This study has stimulated other companies to investigate their own loss experiences and classification of risks; as a result, more equitable rate structures have been adopted by many of them.

The study of variability of loss rates also provided standards by which individual companies could judge the desirability of adopting reinsurance plans. A survey was made of more than 100 farmers' cooperative insurance companies in New York covering the period of 1910 to 1943 and further data were obtained from reports to the State Insurance Department. Those companies which failed characteristically held less than average amounts of insurance in force as well as low surplus reserves. Their expenses, losses, and assessment rates

were high and the last two rates were exceedingly variable. Loss rates were low for companies operating in good farming areas. Moreover, expense rates were low for companies operating in concentrated areas and for those with a large average amount of insurance per policy. Large companies experienced greater stability of loss rates, and therefore of assessment rates, than did the small companies. These findings provide a background of basic information useful to the management of farmers' mutual fire insurance companies, as well as to the State Insurance Department which is responsible for general supervision of these organizations.

A report on a somewhat different project has been made by the Montana station. For a number of years the need has existed for more exacting information relating to monthly prices received by Montana farmers and ranchers as well as the amounts and trends of money income, purchasing power, and general level of living of rural people in the State. Such information has been needed in order to discuss adequately the production plans for Montana agriculture that would show a comparative year-to-year change in crop and livestock production and the general causes and economical implications of such changes. As a result of this work monthly prices received by Montana farmers and ranchers were tabulated for the years 1910 to 1945.

Current information on prices, production, and income was also presented regularly over the past year and is to be continued in the future. A special study of poultry income in Montana was completed under this research program during the past year and outlook information prepared from the results obtained has encountered a strong demand. The data obtained from the study of prices for 1910 to 1945 have proved useful in judging present market conditions and trends and the work done on poultry will be useful to producers in determining production policies. To date, five publications have been released as a result of this investigation.

RESEARCH ON RURAL LIFE

Studies conducted by the experiment stations on the various aspects of rural living have yielded information of vital importance in this very complex age of relatively rapid change. Most of the stations have published useful results from such subfields, for example, as population numbers, composition and change, migration and health, medical facilities, rural housing, farm labor problems, and levels and standards of living.

The Kentucky station reported that the chief instances of mobility in Johnson and Robertson counties were movements of individuals—members of stem-family groups—rather than of families as such. Hence, departure of mature children from their parental homes emerged as the central interest of this study, which gives more attention to migration of rural youth than to other types of mobility. The resident population in both counties was stable and more or less well-established at present locations. Families with the longest mobility radius had more automobiles; families with shortest radius had more radios and telephones. Ownership of automobiles was associated with retention at home of youths over 15 years old. Higher family income, high social participation, and youthfulness of fathers were also associated with lower migration.

In a study by the Vermont station about one-third of the nonfarm families in nine selected towns were visited. They numbered about two-fifths of the open-country population. Many stated that their rural homes were close to their work, but for an even larger group the element of chance was quite apparent. Home conditions, estimated valuation, and frequencies of home conveniences were closely allied to land-class location. Family earnings were higher in the better areas, but this was owing to occupational concentration rather than to land capability. In each occupational group selected for analysis, family income increased with days of work away from home. Use of land, on the other hand, was not important beyond one acre, regardless of location. In general, nonfarm family living was tied in closely with occupation. Families in the upper third of their respective occupational groups had earnings from three to four times as great as had those in the lower third.

The Rhode Island station concluded that the immigrant is never completely transformed. Although he has elected to adopt a new culture and strives to participate in it, he never entirely sheds the culture traits of his native land. Language, food habits, moral concepts, and social responsibilities acquired in his youth are ingrained in him. Thus it is evident that at the present time, in regard to numbers of individuals concerned, the need for constructive guidance in Americanization has increased rather than diminished. The nationalities that revealed the highest degree of integration in most cases had been migrating to the United States since colonial days, or had language and customs similar to our own. The lowest degree of integration was found among those immigrants whose culture was completely alien to that already established here.

The migrant individual, either native or foreign-born, in most cases comes from a rural environment into a city for his initial introduction to a new culture. Outwardly the city is the locale for most of our social integration. In reality, in this complex process which has so much to do with the order, unity, and progressive development of the American way of life, both the rural and the urban have interlocking functions to perform. The talent, experience, and ideas of the newcomer should be viewed as resources, and every effort should be made to utilize these resources in strengthening our own social system.

In a study of the effects of the war on rural life, the Missouri station found that the response of the rural population to the requirements of national defense was wholly satisfying and in complete accord with the traditional patriotism of the farm people of the United States. The alacrity and success with which farmers shifted and directed their efforts to meet the demands of wartime production amply demonstrated their adaptability and the flexibility of American rural economic and social organization. The exceptionally heavy losses of population through entrance into the armed forces and migration to war industries stands as one of the most significant effects of the war upon rural Missouri.

Another important effect has been the marked increase in rural community contacts with the outside world, both at home and abroad. Furthermore, an outstanding influence of the war was the increased prosperity it brought to the rural people of the State. On the whole, rural life was not seriously disrupted by the war. There were fewer

people on farms and they worked harder. Rural organizations did not appear to suffer. Some increase in local cooperative effort apparently occured, chiefly by way of mutual aid. Perhaps the most profound effects have been registered in terms of changes in attitudes, outlook, and habits of thinking.

The Michigan station reported that farmers express favorable attitudes toward the Extension Service; this evidently has become an accepted part of the social organization of the country. They also approved other agricultural programs sponsored by the Government, that is, the Soil Conservation Service, the Farm Security Administration, and the soil improvement features of the AAA. They were less in agreement about the price-control measures of the AAA, though a majority of those interviewed favored some kind of a price-control program. The neighborhood group and the rural school district were used more often than others in a direct way to develop the Extension Service; 4–H Clubs, home economics study groups, and demonstrations were frequently organized on a neighborhood basis. Local trade centers were available for meetings, but meetings in neighborhoods were more feasible. Special interest groups, such as the Dairy Herd Improvement Association, were also used. The number of groups of this type was not large because their members live in several different neighborhoods and their porgrams are specialized.

The perpetuity of groups of this type therefore depends mainly upon the interest of members. Either directly or indirectly, a number of other groups and organizations in the county were helpful to the Extension Service. Among other groups, farmers' organizations, schools, churches, public libraries, and the county public health department should be mentioned. The effectiveness of the Extension Service is increased when its programs are associated with the activities of groups and organizations already present.

Studies at the Kansas station show that information on the nature and changes in population has been necessary to an understanding of many problems of the State. The specific economic value of this information is difficult to determine, but the evidence of its uses are many and varied. Since the information on population is so fundamental to an understanding of human resources in relation to agriculture and industry, heavy demands are made for it on the part of those persons directly concerned with developing economic and social policies in these two broad fields.

The Kansas station also reports that among its 105 counties, Rice County has taken the lead in making a comprehensive plan for a county agricultural center and has made a substantial beginning in application of the plan. The experience gained from the improvement of this agricultural center is potentially valuable in the development of comparable institutions in other counties. The site and the present building in Rice County cost a little more than $1 per capita of its population. The careful advance planning for the institution resulted in acquiring a site that makes future expansion readily feasible. The extensive and increasing use of the center by both rural and urban groups and the absence of adverse public criticism indicate a high degree of public approval. At prewar prices, county agricultural centers satisfactory for Kansas counties could be provided at a cost of $15,000 to $20,000 each where a single building is used, and of

$30,000 to $50,000 each where the center includes a main building, several additional structures, and several acres of land for outdoor facilities.

Pennsylvania's population is not reproducing itself, so the State experiment station reveals. Rapid increase in the number of people in an area increases the demand for commodities, causes land values and rents to rise, and stimulates other adjustments. Likewise, a decrease in population, a change in age level, or a shift in the sex ratio involves numerous changes. For many years, Pennsylvania has continued to lose population to Western and Northern States. In the past three decades, however, there has been a movement of population into Pennsylvania. The proportion of rural population, farm and nonfarm, has decreased over the years. In 1940, 67 percent was urban, 9 percent rural farm, and 24 percent rural nonfarm. The population is rapidly aging as a result of lower birth rates and migration of young people out of the State. More women are working in industry and a much higher proportion of married women are employed than in years past.

ADVANCES IN SOIL MANAGEMENT

The examples of research progress in soil science indicated by the contributions given below signify that research effort has been concluded by the station on the particular segment of each problem discussed or that the accumulated results from the investigation are such as to justify the establishment of certain principles of value to agricultural practice.

The character of research in soil science is such that while work is being suspended on a particular problem in one location an investigation similar in general scope may be started under conditions not previously investigated or where a new problem has developed during the course of the study. This might be illustrated by soils research with fertilizers in which for a considerable number of years attention had been directed toward finding the optimum applications of nitrogen, phosphorus, potash, and lime for various crops. After several years of cropping on some soils the plants became unhealthy and yields declined in spite of application of the fertilizer which previous study had shown best to meet the needs of the crop. This condition prompted research to determine whether some other factor might not be the cause of the decline in yields. This research, as is well known, has shown that under some soil conditions very small amounts of certain elements such as boron, zinc, or manganese frequently represent the difference between success and failure.

Many of the items of soil science research which have been concluded may appear similar in general character; they may differ greatly in fact, however, because of the large variations in environmental conditions existing in the nearly 800 different types of farming areas of the United States. Attention here will be confined to examples that illustrate progress in a few of the more important lines of investigation in soil science research.

INCREASING THE FERTILIZING VALUE OF MANURE

The Vermont station concluded work on a problem involving the effect of amendments on the conservation of cattle manure, the results

of which were of particular significance during the war years of limited-fertilizer supplies coupled with demand for maximum production. During the life of this investigation numerous examples of its research accomplishments have been presented in the annual reports on the activities of the station.

These have involved the use of superphosphate and limestone with the manure, not only to increase the fertilizing value of the manure but also to save the nitrogen which is frequently lost into the air as ammonia when the manure is not properly handled. The results have shown that when superphosphate is added in the gutter at 30 pounds per ton of manure there is a potential saving of more of the nitrogen in the manure—more, in fact, than the nitrogen annually purchased in the whole State of Vermont.

When it is considered that over 2 million tons of manure are produced during the barn-feeding period and that it has a potential crop-producing value of 5 million dollars, the importance of conservation at once becomes apparent. Many of the findings under this study are not only of value to Vermont farmers but have general application throughout the northeastern dairy region. The best method of handling and the best time for applying manure under Vermont conditions were also determined. Furthermore, the value of adding extra nitrogen and potash to manure for grassland as well as to manure for use on legumes was investigated as a possible step toward increased efficiency of labor and machinery.

A finding incidental to the main study concerned the use of small amounts of borax or boric acid for killing fly larvae in the manure; this also provided an easy way to supply the small amount of borax needed for successful production of alfalfa and other crops on boron-deficient soils. These studies resulted in the publication of seven bulletins and articles by the Vermont station, presenting results of the research as a whole and giving practical recommendations for their use by the farmer. In addition, three technical articles were prepared for scientists working on the general problem in other areas.

AIR IN THE SOIL IS IMPORTANT

As the agriculture of our country grows older and efforts toward greater production intensify the farmer's operations on the land, investigators are discovering that crop yields have declined on many of our soils, even though their supply of plant nutrients is inherently ample or has been maintained at high levels. Although it has been known for some time that soils with limited air supplies fail to produce large yields, the real significance of air in the soil in relation to crop growth under field conditions is just becoming evident in certain areas. Only a small beginning has been made by the stations on this problem. Some of the more important preliminary findings from these investigations have been reported in previous years.

Typical for such studies are the results recently reported by the Indiana station and the Department working with a muck soil where air movement was largely limited to the upper 4 inches of soil in comparison with one where the air supply penetrated to 18 inches. Under conditions where the oxygen penetrated to 18 inches instead of 4 inches the yields of carrots went from 3 to 33 tons per acre, onions from 2,250 to 13,750 pounds, sweet corn from 3 to 4.75 tons, table beets from 3.75 to 13.5 tons, and potatoes from 12 to 285 bushels per acre.

Growth of cotton roots in soils from the Mississippi Delta area has been reported in previous years by the Mississippi station under laboratory conditions to be stopped entirely unless the oxygen content was above 1 percent. Best root growth was obtained when the oxygen ranged from 7½ to 21 percent and growth was greatly reduced by oxygen concentrations of 90 to 100 percent. Carbon dioxide concentrations in the soil up to 15 percent had little effect on growth, 30 percent concentrations somewhat reduced growth, 45 percent greatly reduced growth, and no growth occurred at 60 percent.

In related field studies to determine the effect of tillage on plant growth and soil structure on the same Delta soils the station found that neither seedbed preparation nor cultivation appeared to be of any value aside from weed control. Under most of the conditions investigated the undisturbed structure of Houston clay appeared to be better for root and shoot growth of cotton than the disturbed condition brought about by tillage. Cultivation operations were also found to cut plant roots, thereby causing possible additional damage. Although these results suggest that this soil does not need to be prepared or cultivated every year, if weeds can be controlled, there is need for additional investigations as to possible soil management practices that will result in the most desirable plant growth.

Research on the problem of plant growth as affected by tillage and in relation to soil air by the Mississippi station resulted in developing methods of determining injury to roots by cultivation through a study of root pressures. Whereas work on the particular segments of the problem indicated above have been discontinued by the Mississippi station, new investigations have been started which include a study of the fundamental factors bringing about different conditions of soil structure.

The above examples indicate certain possibilities and serve to bring into sharper focus the need for continued research efforts on the problems. The big job still ahead is to determine the soil conditions best suited for growth of various crops and to develop methods of soil management that will result in the desired balance between air, water, and plant nutrients in the soil.

SAVING SOIL AND WATER PAYS

Answers to questions on the effects of soil and water conservation on crop yields, livestock production, soil maintenance, and cash returns to farmers are being obtained under various farming conditions throughout the country.

The Illinois station and the Department found from extensive long-time studies that conservation farming increased crop yields by 9 to 21 percent in six different areas of the State. In seven different areas and at 1945 prices, 160-acre farms with well-developed soil conservation programs in comparison with farms of the same size without such programs gave increased incomes of $780 to $1,330 as benefits from conservation. Even when compared on the basis of farm income from 1935 to 1939, the conservation farms gave increases of $460 to $780 annual income. Besides increasing current income, conservation practices prevent soil erosion and loss of capital resources and thus leave the farm more productive than it was before.

In similar studies of economic returns from soil conservation practices, the Wisconsin station with the Department found that under

Wisconsin conditions soil-conserving farmers surpassed their neighbors not using such practices by greater increases in crop and nutrient yields, in livestock numbers, and in gross receipts and net incomes. Soil-conserving farmers were able to increase their output of all the important feed crops—corn, small grain, and hay, whereas other farmers increased only their grain and corn yields. Considered on the basis of total nutrients produced, the increase was 20 percent for soil-conserving farms and 12 percent for the others.

In comparisons of contour cultivation with terracing on wheatland the Oklahoma station and the Department found that yields the first 2 years after terracing averaged about 1½ bushels per acre less than on land cultivated with the slope, but that in the next 3 years they averaged nearly 2 bushels more.

From investigations in four areas of South Dakota the station and the Department reported as benefits of contour farming an increase in yields for row crops of 28 to 38 percent and for small grain of 6 to 15 percent over areas where contour planting had not been used.

Another long-time investigation by the Texas station and the Department in the western part of the State, involving a comparison of rows up and down the slope, contoured rows, and closed level terraces, gave the following results: Contouring alone was a little less than one-half as effective in increasing cotton yields as were closed level terraces. The average yield of lint cotton from straight rows was 119 pounds and from closed level terraces 175 pounds. The value of the lint and cottonseed produced with closed level terraces over the 20-year period was $191.41 per acre more than where rows ran up and down the slope. Saving all of the water resulted in an increased return of $9.57 per acre per year. Reducing runoff by 1 acre-inch gave an increased yield of 20 pounds of lint which, together with the seed, had a value of $3.48; the value of 1 acre-foot of water saved was thus $41.52. The plant food lost with the 75 tons of soil eroded with the 55.01 inches of runoff and with the crops removed was six times greater than the plant food removed in crops on closed level terraces.

Working with a different crop under humid conditions the New York State station and the Department found that the yield of grapes on contoured rows was almost twice as large as on rows going up and down the slope.

These examples, together with results in previous reports on the stations, show that farmers under widely varying conditions can, through the effective use of simple and inexpensive farming systems, increase yields and secure greater returns through conservation farming practices.

ORCHARD MULCHING INCREASES PLANT FOOD

The beneficial effects of mulching for increased moisture intake and maintenance of soil-moisture supply have been known for some time. The effects of mulching on the supply of plant nutrients have not received as much attention and consequently are not so widely recognized.

Field and laboratory studies conducted at the Ohio station over a period of years, which were discontinued during the past year because of loss of personnel, have provided valuable background information on the problem, as well as indicated the need for more basic research

on the problem of supply and movement of plant nutrients through orchard soils. On areas receiving clean cultivation with cover crops and treated with potash fertilizer as well as on areas in grass, chemical tests indicated very little downward movement of available potassium below 6 inches even after a 10-year period of treatment.

On areas under heavy mulch which had been maintained for 22 to 38 years with no potassium added other than that supplied with the mulch, tests showed that the soil contained a large supply of potassium available for use by the tree to a depth of 24 to 32 inches.

The use of a mulch had no effect in increasing the downward movement of the available calcium applied annually at a rate of 40 pounds of finely ground limestone per tree for 3 years. The depth of penetration of phosphorus into the soil when applied as 20 pounds of superphosphate per tree was increased by mulching.

To the practical orchardist these studies show the value of a mulch such as straw in providing large amounts of potassium, as well as in rendering soil conditions favorable for the downward movement of potassium and phosphorus to a level in the soil where they will be available for use by the trees.

SOIL FERTILITY AND CONTINUED HIGH PRODUCTION

The demand for maximum production from our soils continues to exert a heavy drain on fertility resources and calls for more efficient use of both soil and fertilizers. In order to meet this demand and still provide for our own future national security, which requires a productive soil, it is essential that every effort be made to increase and apply our knowledge of soil-fertility practices that will give increased production and still provide for soil maintenance.

Long-time soil-fertility studies conducted by many stations have provided much of the necessary basic information on practices that will give the greatest yield of a particular crop under certain soil conditions. For example, long-time chemical studies of several thousand Texas soils, combined with field and laboratory investigations by the Texas station, have shown that most soils of the State are deficient in phosphorus. Many of the lighter soils were found to be deficient in nitrogen and some may also be deficient in calcium and magnesium. The knowledge of the nutrient status of many of the soils of the State had provided considerable information relative to a number of factors which influence and condition the efficient and economical use of fertilizers. The value of this knowledge of soil needs is illustrated by the increase in use of fertilizers in the State from about 31,000 tons in the 1932 to 1933 season to nearly 300,000 tons during the 1945 to 1946 season.

Under Kansas conditions the results of long-time soil fertility studies by the station indicate that the use of improved crop rotations, tillage practices, fertilizers, and manure can have a marked effect on yield. The station workers estimate that from 4 to 6 million more bushels of wheat could be grown on the eastern two-fifths of the State if the improved practices were used on the approximately 1½ million acres involved.

PUTTING SOIL SCIENCE TO WORK

What crops will grow best on my farm? What treatments does my soil need to make it yield its best? What yields can I expect? With

questions like these confronting the farmer every day, the Illinois station set out to develop and present in a single bulletin and in a form that could be used by farmers, all the scientific and practical information obtained about the soils in one county of the State.

This publication on Cass County soils represents an outstanding step forward in making the scientist's knowledge of the behavior of soils available in a form that can be readily appreciated by the farmer. In addition to a description of the soils of this county, information is presented on yields which can be expected from the principal field crops on the different soils under a good system of soil management. The need and benefits of such practices as fertilization, liming, erosion control, good crop rotations, use of crop residues, and the fulfilling of possible needs of the soil for minor elements are presented.

BETTER HEALTH FROM SOIL ORGANISMS

The discovery by the New Jersey station of the antibiotic, streptomycin, in its researches on soil microbiology has received world-wide publicity because of promising results shown in the treatment of certain diseases. In connection with the research on streptomycin it is of interest to point out that the discovery of this important antibiotic was preceded by several years of intensive research. The earlier work at the New Jersey station on soil organisms that produce antibiotics involved studies of many different bacteria, molds, and actinomycetes that live in the soil.

The station workers have isolated eight antibiotics during the period of the investigation. They are actinomycin, clavacin, fumigacin, chaetomin, streptothricin, micromonosporin, streptomycin, and grisein. Of these, the most widely known is streptomycin, which is not poisonous to animals and is active in human and other animal bodies. It is now being used successfully against such important diseases as urinary infections, tularemia, influenza, meningitis, and whooping cough, and it looks promising for the treatment of brucellosis, typhoid, plague, cholera, and tuberculosis.

Practical developments in relation to this antibiotic are illustrated by the fact that private industry has invested approximately $20,000,000 for its manufacture. Some 10 or 12 companies are now concerned with this process, one of them is already producing more than 200 kilograms of streptomycin a month. The price of this antibiotic was reduced from $20 a gram in September 1946, to less than $4 a gram in the fall of 1947.

IMPROVED FIELD CROPS AND PRODUCTION PRACTICES

Demands for bread and feed grains, fibers, oilseeds, and forage for domestic use and in increasing volumes to cope with needs for international relief are being met by the experiment stations with improved crop varieties noteworthy for higher yield, resistance to disease, insects, and environmental hazards, suited to mechanized production, adapted to specific regions, and possessing superior technological qualities. Higher yields and better quality of products also are resulting from application of more efficient tillage, soil fertility, cultural, and harvest practices developed as products of station investigations. Pasture and range research is also bringing into use better methods of establishing and managing forage areas capable

of carrying larger numbers of livestock to provide for current and future requirements for meat and milk. Selected examples of completed investigations of this character and some promising results of continuing efforts are set forth below.

CROP COMPOSITION INFLUENCED BY ENVIRONMENT AND VARIETY

A knowledge of their chemical composition is essential to the best use of important crops as food and feed, for the varied and rapidly increasing industrial applications of plant products in general, and for the maintenance of proper soil productivity after removal of essential elements in the harvested material. The Illinois station, experimenting with several treatments for corn, oats, and wheat on fertile and poor soils, found that in contrast to the residual vegetative parts of mature plants, the seed of cereal grains are influenced but little in composition by environment. The percentages of the several nutrient elements in cereals have tended to decrease with increase in yields; this result is attributed to the ability of the plant to "stretch" the available supply of a nutrient, and thus to make full use of all growth factors in producing a maximum yield. The total amounts of nitrogen, phosphorus, potassium, calcium, and other nutrients removed per acre are, on the other hand, directly proportional to the yields.

Furthermore, plant composition has been influenced markedly by weather conditions. Another pertinent observation was that crops growing on the same land in two succeeding years have varied more in composition than crops grown with different fertilization in the same year. These results also suggested that, in breeding corn for high-protein content in the grain, values obtained in one region may not be expected to follow with the same corn when grown in another region. Moreover, character of soil and possible local variations in weather may cause wide variations in crude protein content. The need is thus evident for similar studies in different sections of the country to determine the magnitude of possible changes in mineral composition, amount and nature of proteins, carbohydrates, oils, vitamins, and other constituents of nutritional and industrial value.

POTATO YIELD, MATURITY, AND SCAB INFECTION INFLUENCED BY SOIL REACTION

Potatoes, one of the leading cash crops of New York State, are produced in soils differing widely in both organic matter and soil reaction. The latter factors, as found by the New York (Cornell) station in a prolonged study recently completed, has a great influence on the yield and growth and also on the production of scabby tubers. The highest tuber yields, as well as the largest plants, were made in soils with reactions ranging from pH 5.2 to 6.5; the percentages of dry matter and starches were also generally higher in this intermediate range than in higher or lower reactions. Potatoes grown in soils either of lower or of higher pH values made lower yields, had fewer tubers, and matured earlier. The highest percentages of scabby tubers were found in soil with reactions between pH 6.5 and 7.5, scab infection decreasing at higher (alkaline) and lower (more acid) reactions. Additions of organic matter—for example, corn or rye green manures—lowered the soil pH temporarily and decreased the amount of scab accordingly.

These findings have a very substantial economic value, since in New York State thousands of acres of potatoes are grown on soils with reactions below pH 4.8 and above pH 7.0. To obtain large yields of tubers free from scab, soils of too low pH may be rendered more suitable for production by proper liming and soils too high in pH may be improved by adding sulfur. Further increases in yield and reductions in the amount of scab may be obtained by incorporating organic matter into the soil.

NEW WHEAT FOR GEORGIA

Chancellor, a new soft red winter wheat developed by the Georgia station with the Department and ready for distribution to farmers in 1948, is resistant to leaf rust, makes good yields, and has a good milling quality. It has outyielded important varities in extensive tests in the Piedmont area and also appears to be well adapted to the mountain areas of Georgia where it made 67 bushels per acre in 1947.

Chancellor has a strong straw, stands well for combining, and is similar in height and time of maturity to Sanford, another superior variety developed for Georgia; it is, however, resistant to more races of leaf rust than Sanford and is also winter-hardy. State-wide adoption of such productive varieties outside of the Wheat Belt will supply the needs of currently deficit areas and permit diversion of wheat products of surplus States for purposes of relief.

IMPROVING SAGEBRUSH AND CHEATGRASS RANGE

Millions of acres of range land in Utah and other States of the intermountain West support sagebrush (*Artemisia tridentata*), with but little palatable undergrowth. Other vast acreages are covered by downy-brome or cheatgrass (*Bromus tectorum*), which provides fairly good forage but is edible for only a short season and is of low value for soil stabilization. Competition of sagebrush and cheatgrass must first be removed before seeding to perennial grasses on these lands becomes advisable. The Utah station, concluding a series of intensive studies, finds that fall disking after seed germination eradicates cheatgrass better than does spring or summer disking. Sagebrush has been eradicated best and cheapest by controlled burning, preferably in dry weather from July 1 to about October 15 and from noon until early evening; burning, however, has not been a practicable means of eliminating cheatgrass.

Crested wheatgrass, bulbous bluegrass, and Sandburg bluegrass (*Poa secunda*) have competed best with cheatgrass, and the two grasses *Agropyron elongatum* and *A. trichophyorum* have proved very promising for dry lands. Early fall seeding, most effective by drilling, was found best for cheatgrass. On sagebrush land, grasses are drilled or broadcast after the wheatland plow. Rye is best broadcast ahead of the drill and small seeded grasses behind it; grasses with large seeds may be broadcast either way. Areas with less than 15 inches of precipitation annually are likely to be hard to seed with surety.

With careful use and scientific guidance, range reseeding is thus seen to have enormous possibilities for increased forage production and soil conservation. Improper methods may cost the rancher heavily and gain him nothing.

PROMISING NEW SOYBEAN FOR THE CORN BELT

Each of the new varieties of soybean successively released has been noted for one or more qualities in which it surpassed the older strains; these include such characters as yield time of ripening, oil quality, resistance to shattering or lodging, and adaptation. Hawkeye, selected by the Iowa station and the U. S. Regional Soybean Laboratory from a cross between Richland and Mukden, combines early maturity and resistance to lodging with high yields and oil content. Its adaptation extends from adjacent areas of Nebraska and South Dakota east into northern Ohio.

Compared with the widely grown Lincoln, also a superior recent development, Hawkeye matures a week earlier, is 3 inches shorter, and stands more erect; it about equals Lincoln in oil content and acre yield of beans. Seed would be available to farmers for increase in 1948. The Hawkeye soybean is a definite achievement of station cooperative research which will help supply the national and world needs for food and feed.

VIGO, NEW DISEASE-RESISTANT WHEAT

One of the greatest hazards in the production of soft winter wheat has been the destructive fungus disease, leaf rust. Prolonged efforts by the Indiana station and the Department to find resistance to this disease and to breed that resistance into desirable soft red winter varieties have resulted in Vigo.

This new soft red winter wheat, released to certified seed producers in 1946, was produced from a cross of the loose-smut-resistant variety Trumbull with a leaf-rust-resistant Fultz selection. Both parents have high-quality grain characteristics. The merits of Vigo wheat include moderate resistance to leaf rust and high resistance to loose smut and mosaic disease, superior bushel weight of grain, and high yield. It is a medium-season, beardless, white-chaff wheat, having strong straw and a dark-green foliage in both seedling and headed stages. Vigo has shown winter hardiness superior to that of most good-quality soft red winter wheats and about equal to that of Fairfield.

Vigo has outyielded standard varieties under severe rust attack and approximately equaled the better varieties where rust was not a factor. The new variety has also shown superior yielding ability in the other States cooperating in a uniform yield test. Furthermore, its milling and baking qualities have equaled or surpassed the soft red varieties now considered as standards by the soft-wheat milling and baking trades. Extensive planting of Vigo wheat should prove highly advantageous to farmers in the soft red winter wheat area where it is adapted.

A PRODUCTIVE DISEASE-RESISTANT SYNTHETIC RED CLOVER

Red clover, an important crop in Indiana and other Corn Belt States, fits well into standard crop rotations for hay and aftermath pasture, as well as for seed production. Need has long existed for productive winter hardy varieties that would endure summer drought in seedling years, resist attacks of anthracnose, and suffer but little from mildew. A new synthetic strain composed of three superior selections was derived by the Indiana station from a productive winter-

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and summer-enduring little red clover by inbreeding, that is, by controlled pollination involving the use of several hundred plants caged with bumblebees, subsequent rigid selection, and finally by cross pollination to maintain maximum vigor. It combines good hay and seed production, vigor, much winter hardiness, a high degree of resistance to northern anthracnose, and, in particular, has some resistance to mildew. The new synthetic strain, now being multiplied for release, promises to become a valuable addition to Indiana agriculture.

FRUITING AND SHEDDING OF COTTON

Heavy production of bolls with a minimum amount of shedding is essential to profitable yields of cotton. In fact, estimates are that one more good boll on every stalk of cotton in Arkansas, Louisiana, Oklahoma, and Texas would increase the annual yield of lint from this area by 900,000 bales. In a recently completed investigation, aimed at more efficient production, the Texas station found that cotton plants become well fruited under conditions favoring production of many blooms, little shedding, and moderate vegetative growth. Moreover, adequate sunlight is an important element in these environmental conditions. Variations in the amount of light, such as accompany periods of cloudy weather, short days, and close spacing of plants, have resulted in impairment of fruiting and excessive vegetative growth. The heavy shedding of young bolls often noted by growers after rainy periods seemed to be caused by the interruption of high sunlight intensity rather than by the direct effect of rain on the flowers. Modified light conditions and other factors that induce shedding were found to hinder photosynthesis and thus reduce the carbohydrate content of the leaves.

Certain varieties—including Stoneville 2B, Coker 4–in–1, Deltapine 14, Half and Half, Roldo Rowden, and Washington—were generally less sensitive to unfavorable variations in light than were several other cottons tested—including Qualla, A. D. Mebane Estate, Rogers Acala, and Lone Star. Such differences in sensitiveness of cotton varieties to unfavorable light conditions brought out the importance of careful selection of varieties for each region according to prevailing weather conditions during the fruiting season, and demonstrated to breeders the need for attention to these inherent varietal differences. Other practices recommended to growers from these investigations included the use of soil-moisture conserving practices; maintenance of high, well-balanced soil fertility with as high a nitrogen level as practicable in keeping with available soil moisture; and allowance of adequate spacing of plants to prevent serious shading when they reach maturity.

ENVIRONMENTAL EFFECTS ON COTTON SEED AND LINT

The value of a cotton crop is related closely to the grade or quality of the fiber and seed. The worth of the fibers is determined largely by the size and strength of the yarn they will produce, the percentage of oil is a major factor in determining the value of the seed, and the percentage of protein is the most important influence in determining the value of the cottonseed meal. The Alabama station with the Department concluded during the year a prolonged series of studies seeking

the influence of both varietal and environmental factors on the seed and fiber properties of cotton.

Soil moisture was found to be the dominant factor influencing the several characters. When adequate it was responsible for increased weight per boll, weight per seed, weight of lint per seed, oil content of seed, length of fibers and maturity, although resulting in decreases in percentage of lint, protein content of seed, and breaking strength of fibers. The weight per boll and weight of seed were increased by applications of nitrogen, phosphorus and potassium; the weight of lint per seed was but little affected by fertilizer treatment. Oil content of seed was increased by applying phosphorus and potassium, yet was not affected by calcium, magnesium, or nitrogen. The protein content of the seed was increased by applications of nitrogen but decreased by applications of phosphorus and potassium.

The percentage of fuzz was affected mainly by variety and location, but by none of the factors studied in the environment. The soil type had a slight influence on the characters studied but, when moisture was adequate, the kind of fertilizer had little effect on fiber properties. Under drought conditions nitrogen increased the breaking strength and decreased the fiber length. Variety proved very important in its effects on all of the properties studied.

These results emphasize to the grower that desirable varieties must be planted if superior fiber qualities are to be obtained, for irrigation has been the only treatment that affected them readily. The oil and protein contents of the seed, however, may be favorably changed by proper fertilization as well as by the use of desirable varieties.

FERTILIZERS FOR EMERGENCY FOODS AND FEEDS

The emergency demands for foods and forage during wartime and postwar years encountered in many areas only a meager store of essential information on the best methods for highest crop yields. Vital facts of this type were obtained by the Vermont station in research recently concluded. Among other findings, the Vermont workers determined that field beans would make highest yields when 400 pounds of 5–10–10 fertilizer were applied near the seed at planting time and that they also responded to magnesium. Such fertilization has given about 5 bushels more beans than the acre average of 10 bushels.

Silage corn has responded like beans to similar rates and ratios, but has shown a greater need for nitrogen. Potatoes have made best returns from the application of 1 ton per acre of 5–10–10 fertilizer, although they have also benefited from magnesium on all old fields and on some fields from borax. Potato yields have been increased 50 bushels per acre by better fertilization and application of magnesium. Magnesium alone resulted in a 10-bushel gain; this means an increase of at least $150,000 per year from the 14,000 acres of potatoes grown in Vermont.

A NEW VARIETY OF FEED BARLEY

High yield, resistance to stem rust, stiff straw, high content of protein, and, worthy of note, some resistance to grasshoppers are advantages that recommend Feebar, a new variety of feed barley, to farmers in South Dakota. Feebar barley, derived by the South Dakota sta-

tion from Peatland × Vaughn, is a six-rowed semi-smooth awned variety with a stiff straw, and moderately large and plump kernels. It is easily distinguished from other barleys grown in the State by the dense erect head and long rough-tipped spreading awns. It is midway between Spartan and Wisconsin Barbless (38) in date of heading, but like Trebi is more resistant to grasshoppers than Spartan and Odessa and far more resistant than Wisconsin Barbless.

The beards are tough and hard to remove from the kernels, with the result that low test weights may often be obtained, yet care in adjustment of concave settings and cylinder speed in threshing helps to improve the test weight. Results on widely different soil types in South Dakota show Feebar to be adapted and capable of displacing some of the older barleys commonly grown.

A NEW DISEASE-RESISTANT FEED WHEAT FOR SOUTHERN TEXAS

Seabreeze wheat, a new disease-resistant variety, has been developed by the Texas station and the Department to meet the demand for a feed wheat adapted to winter growing in extreme southern Texas where a 12-month growing season prevails.

Derived from the cross (Mediterranean × Hope) × Gasta, Seabreeze carries a rare combination of characteristics bred from many sources, which enable it to meet the special requirements of southern Texas. Vigorous, leafy growth during the short cool days of winter, when most varieties tend to remain dormant, makes the new variety of special value for winter pasture, leaf meal, hay, soiling, or silage.

Seabreeze is resistant to the common air-borne diseases such as stem rust, leaf rust, loose smut, and mildew, so fatal to the common varieties of wheat in the coastal area of Texas. Its grain has an exceptionally high protein content, averaging around 16 percent in the lower Rio Grande Valley and Coastal Bend areas. This is of special value for poultry feed, and for supplementing the low-protein locally grown grain sorghums. The strong erect-growing straw and an awnless nonshattering head make this new variety ideal for direct harvesting with the small row-crop type combines in general use for harvesting grain sorghums in the region.

Under irrigation in the lower Rio Grande Valley, Seabreeze produces good yields of hay within 90 days from seeding, and ripe grain in 120 to 130 days. October 1 plantings are ready to be made into hay by January 1, or can be pastured through November and December and then harvested for grain in March. Its early maturity also allows ample time, however, for preparing the land for a summer crop such as Sudan grass, grain sorghum, or even rice after wheat. This wheat, grown for winter pasture and grain followed by a summer feed crop such as Sudan grass, may go a long way toward solving the livestock feed problem in the areas where it is adapted. Poultry raisers, particularly turkey producers, will find this new wheat of value, both as green-pasture and as "grain-pasture" crops.

Although its milling properties are satisfactory and the flour is suitable for general purpose home use, this is of minor concern to the southern Texas farmer who will grow it largely for pasture and feed for his livestock. Heretofore, large quantities of northern-grown high-protein feeds, including good bread wheat, have been shipped

in to supplement locally grown low-protein feeds such as grain sorghums, corn, and rice. By growing Seabreeze to supply their own protein supplement, farmers will be releasing the northern-grown good-quality bread wheat for other uses. Of about 80,000 bushels of seed produced in 1947, possibly half would be available for planting.

MAGNOLIA—A NEW EARLY MEDIUM-GRAIN RICE

Rice growers continue to seek improved varieties that will replace those already in production or supplement them in extending the harvest period. Magnolia, a newcomer in the Louisiana rice fields, has better disease resistance, strong straw, and easy threshing, milling, and cooking qualities equal to Blue Rose.

Magnolia rice, developed by the Louisiana station and the Department by selection from improved Blue Rose × Fortuna, is characterized by a general greenish coloration when headed; shows little indication of white tip, has some resistance to straight head, and has not been severely affected by row 4 of cercospora leaf spot. It matures in from 130 to 135 days, being notably earlier than either parent, and attains a height averaging 46.4 inches. The straw is stiff and resistant to lodging. Magnolia threshes much easier than any other medium-grain type, but does not appear to shatter so much as some of the long-grain varieties. Thus it appears suitable for harvesting by either the combine or binder methods.

The new variety has yielded similiarly to Zenith and Early Prolific in Louisiana station tests, and slightly lower than Zenith in Texas and Arkansas station tests, but was well ahead of Early Prolific. Magnolia has compared satisfactorily with Blue Rose and has surpassed other early varieties in milling quality. It resembles Blue Rose in cooking quality. Estimates are that more than 22,000 acres or 3.6 percent of the Louisiana rice acreage were growing Magnolia in 1947.

A NEW HARD-SEEDED CRIMSON CLOVER

Crimson clover is in many ways an ideal winter legume for grazing, soil improvement, and erosion control under many conditions in the South, although its wider use has been handicapped by the tendency of the seed to shatter and the uncertainty of getting a stand in the fall. Modern tractor-operated combines have enabled the harvesting of seed from large acreages during the short period between ripening and shattering. The risk of stand losses has been reduced greatly by the use of Dixie, a new hard-seeded variety.

Dixie crimson clover, developed by the Georgia station and the Department, is a synthetic variety composed of the Thornton strain from northeast Georgia, Hardy from western Georgia, and the Allen strain from central Georgia; each of these varieties has volunteered successfully for 20 years or longer. Dixie, which combines their good characteristics, has a much larger percentage of hard seed than has common crimson clover. Germination of hard seed is delayed until autumn when the soil moisture is sufficient to support the seedlings, where as common crimson clover germinates in summer, after light showers, when the seedlings may be killed by drought. The popularity of the new variety, winning favor from the Gulf Coast northward, is due to its ability to volunteer year after year in cultivated fields

and pastures. It has made excellent winter grazing from December 1 until April 1. On fertile soil, grazing has helped seed production in that vegetative growth is suppressed and abundant stooling is promoted. When a seed crop is wanted, cattle are taken off the clover about April 1 or whenever blossoms appear. The station has shown that a good crop of crimson clover plowed under is equivalent to 8 to 10 tons of manure or 400 to 500 pounds of sodium nitrate per acre. Demand for Dixie seed in 1947 greatly exceeded the supply.

NEW DEVELOPMENTS IN HORTICULTURE

Many of the horticultural researches conducted by the stations are necessarily of long duration, particularly those dealing with the development of new fruits and vegetables to meet specific needs. New developments including the growing importance of new methods of preservation, such as freezing, and the greater realization of the importance of various nutritive properties, such as the vitamins, provide a never-ending list of new objectives for intensive research. Much of the progress in horticultural research as in other agricultural fields occurs as steps in long-continued studies, as, for example, the introduction discussed below of the Bonita peach by the California station. In view of the ever-changing nature of agriculture itself, research must also be modified to keep in line with the more pressing problems. The results of a few studies that reached a status of profitable fruition during the past year are discussed.

A NEW PEACH FOR SOUTHERN AREAS

Bonita, a new peach originated by the California station at Riverside, marks a milestone in the development of varieties which will flower and fruit normally under southern conditions. The new variety resulted from crossing standard peaches such as Elberta with a South China type known as Peento or Saucer peach which, because of long centuries of growth in southern climes, had become adapted to mild winters. Bonita promises a great deal not only for southern California but also for all southern areas of the United States where peach growing has been precarious because of the mild winters. Peaches like other northern plants need considerable winter cold to break the natural rest into which the tree goes in late autumn. Without adequate cold, their flower and leaf buds fail to open normally in spring, with resulting poor crops and early death of the trees.

As with most fruit trees, a considerable number of years is required to develop a peach tree from the time the seed is sown until the fruiting age is reached. To obtain the desirable combination of good quality fruit and healthy vigorous tree, many hundreds and even thousands of seedlings may need to be grown and observed. Thus the Bonita peach represents one completed phase in a long series of painstaking researches.

The name Bonita, from the Spanish word meaning pretty, was selected because of the attractive appearance of the fruit—yellow with a blush of red. The flesh is yellow, the fruit is freestone, and the quality is rated by the station as "good," with value for fresh use and for home canning. Peaches such as Bonita provide fruit of this

delectable species for people living in areas where peaches are rare and thus desirable for providing a pleasant change from purely tropical fruits such as citrus.

LEAF COLOR INDICATES NUTRIENT NEEDS OF APPLE TREES

The problem of fertilizing apple and other fruit trees has long concerned fruit growers. Apparently because of their extensive root systems, fruit trees are better able to collect nutrients from the soil than are annual crops, and do not reflect deficiencies so quickly. In many areas, nitrogen has been the only fertilizing material to show benefit to fruit trees. The growers learned early that too much nitrogen may cause excessive vegetative growth and prevent the desirable development of color in the fruit; this is particularly true for red-fruited apple varieties such as Staymen Winesap, McIntosh, and Baldwin. Hence, it was only natural that the stations located in important apple producing States should have been asked by the growers for reliable information on fruit-tree fertilization.

Important contributions have come from several States, including New York, Ohio, Pennsylvania, Virginia, Washington, and others. Certain observations recorded by the Ohio station are reviewed here because the project was brought to a temporary close by the untimely death of the principal worker. In undertaking a specific investigation of orchard fertilization in the spring of 1944, this station had not only a background of many years' study, but also the apple-tree plots to work in; some of these plots had been heavily mulched with straw, others were in continued clean cultivation, and still others in grass sod. To these were applied various amounts of nitrogenous fertilizer.

Among the interesting and valuable findings was the discovery that the total nitrogen content of the leaves bears a definite relation to their color as well as to the yield and color of the harvested fruits. The nitrogen in the leaves reflected the nutrient condition of the tree and was shown to be a useful and reliable index to the nitrogen requirements of the apple tree. Moreover, nitrogen content of the leaves was not constant but exhibited a steady decline as the season advanced.

The amount of fruit on the tree affected also the nitrogen content of the leaves; trees bearing a heavy crop had less nitrogen in the leaves than did the nonbearing or lightly bearing trees. Both from these experiments and from observations in several commercial orchards, the stations workers concluded that leaf analyses and leaf color are valuable indexes to the nitrogen requirements of the apple and presumably also of other Temperate Zone fruits. In several of these commercial orchards, there were definite indications that the growers had applied too much nitrogen to the soil for best results. With a few careful observations, the grower could thus save money on fertilizers and at the same time harvest a more attractive and marketable crop.

EXCESS OF BORON INJURES FRUIT TREES

Boron is one of the so-called minor elements necessary for the growth of plants, yet when present in appreciable quantity can be distinctly harmful. In the realization that certain orchards might be suffering from an excess of boron, the California station initiated in 1935 a series of field and laboratory experiments to determine the extent and nature

of the boron problem as related to deciduous fruits. Excesses of boron sufficient to cause serious injury to various fruit and nut trees were recorded in several areas, particularly where the irrigation water applied to the orchards contained excessive amounts of this element. In one area, trees were so severely injured that whole orchards had to be cut down. As the study developed, other areas were located, particularly in the Sierra Nevada foothills where the boron content of the soil was inadequate for the best growth of the trees.

Concurrently with the field operations, controlled laboratory experiments were conducted in which various species of fruit plants were grown in pots of soil to which measured amounts of boron were added. One interesting finding was that the olive tree is considerably more resistant to excess boron than are the peach, apple, apricot, and plum.

From a practical standpoint, the correction of excess boron in the soil presents a much more difficult problem than correction of a deficiency. In the latter case, borax may be applied to the soil with care not to exceed the established requirements of the plants being grown. Determination of locations in California where boron particularly in the irrigation water is in excess should lead to a more selective use of such areas with replanting of boron-tolerant crops where possible. More conservative use of irrigation waters containing boron would also prove beneficial. In some cases, water supplies carrying less boron may be available.

WINTER-HARDY FRUITS FOR MINNESOTA

Fruit growing in Minnesota and other nearby North Central States has been a hazardous enterprise because of the exceedingly cold winters. Frequently, the change from summer to winter conditions occurs with devastating abruptness, failing to give trees and plants adequate time for adjustment. As a result, many of the so-called eastern varieties of apple, pear, plum, and other species fail when grown in north-central areas. This failure led to serious losses and bitter disappointment to the settlers and in the early development of the State agricultural research stations. A number of experiments were begun in the breeding of fruits that could withstand the exacting climate. Iowa, Minnesota, and South Dakota are among the States that have made important contributions toward the development of hardy fruits for their respective areas.

One such study, closed this past year by the Minnesota station, yielded valuable information for the fruit breeder as well as improved new fruits for the grower. Hardy parental material was established as a prerequisite to the development of hardy new fruits. Observations on various groups of seedling plums showed that the hardiness of certain native American plums was transmitted in a high degree to the seedlings and that seedlings resulting from crosses between hardy and tender parents differed in their reactions to temperature.

Chemical studies of apple wood collected from hardy and tender varieties showed that moisture content, sugars, pentosans, and certain nitrogenous fractions are not reliable measures of hardiness. Observations on living plant materials such as apple shoots exposed to controlled low temperatures proved a more reliable index of hardiness. The use of such tests has aided greatly in selecting hardy parents and in eliminating quickly from the numerous progeny those individ-

uals which could not meet the exacting climatic requirements. The use of this hardiness has resulted in great savings of land space and time and has speeded up the breeding programs to a marked degree.

From a practical standpoint, the results of this and associated experiments have proved of inestimable value. Actually the investigations have given Minnesota the nucleus of a stable fruit-growing industry which includes apples, pears, plums, raspberries, and strawberries of excellent quality and adequate hardiness to survive its exacting climate. More varieties are needed to round out the picture but a very important beginning has been recorded.

HARDY APPLE TREES FOR NORTHERN MAINE

In areas such as northern Maine, there occur at irregular intervals, unusually cold winters which cause disastrous injury to apple orchards. Frequently, when snow is absent, the trunk and root crown as well as the top of the trees are killed or badly damaged. Growers noted early that when an apple tree consisted of a top variety grafted upon a hardy trunk it had a much better chance to survive critical temperatures. To aid the growers, the Maine station initiated a study, still in operation, to test various apple varieties as potential trunk formers for commercial apples such as McIntosh. With the aid of the Department, hardy apple materials were obtained from various areas including Russia and tested in comparison with our best known hardy stocks such as Hibernal and Virginia crab. Such research is slow because after testing for winter hardiness the selections must be further tried out to see whether they are able to unite successfully with cultivated apples such as McIntosh and Baldwin.

Some interesting findings have been reported from these investigations. The understock apparently may influence the hardiness of the top variety; for example, Baldwin on Virginia crab was reasonably hardy whereas Baldwin on Hibernal displayed tenderness. Certain combinations of stock and scion proved unsuccessful; for example, Gravenstein was incompatible with Virginia crab. Certain of the imported stocks were shown to have a promising degree of hardiness. Although this is a preliminary report, the evidence is at hand that continued effort will result in a stable apple industry for northern Maine and incidentally be helpful in areas of comparable climate. The intense interest of Maine apple growers in these activities is shown by their development of a cooperative nursery for producing apple trees on hardy stocks; this was a direct outcome of the investigation.

BETTER CULTURAL METHODS INCREASE STRAWBERRY YIELDS

That consideration of simple cultural requirements may often lead to important increases in yield was shown by the North Carolina station and the Department working with the strawberry. Based on records taken in experimental plantings at Willard and near Raleigh, the workers found that plants set in the field a year prior to fruiting yielded 7,864 quarts of berries per acre, as compared with 5,839 and 3,711 quarts for June- and September-formed runners. These results emphasize the need for encouraging and protecting early spring runner plants in order to promote large yields. Spacing of plants was also studied but led to the conclusion that varietal growing habit is a more important consideration. Spacing of Klonmore and Massey plants

gave notable increases in yield as compared with the usual matted row, but in the case of Blakemore and Missionary there was no significant difference between the two systems of culture.

Strawberry growing is an important industry in North Carolina as indicated by an average of 6,210 acres over the 10 years, 1934 to 1943. Production during this period averaged 534,000 crates per year and yielded total returns of over 1½ million dollars. Production decreased sharply during the war years because of the shortage of labor, but the gross returns were high on account of the better prices obtained.

STRAWBERRIES SUFFER FROM HOT, DRY WEATHER

Although the strawberry is normally a cool-season crop, the plants grow throughout the summer. Under the hot semiarid conditions of Oklahoma summers, young strawberry plants frequently fail to root successfully—apparently because of high temperatures at the soil surface. This failure to root not only results in the loss of young plants but also constitutes a serious drain on the mother plants in their endeavor to supply moisture and nutrients to the young runners. Seeking an explanation of the factors underlying this injury, the Oklahoma station grew a series of strawberry plants in pots which could be subjected under controlled conditions to various temperatures over measured periods of time. All exposed roots were killed by temperatures of 120° F. continued for 4 hours or more and by temperatures of 124° or 128° maintained for 2 or more hours. In general, the older plants proved more resistant to adverse conditions than the younger ones. Moreover, at temperatures of 124° and 128°, the stems of the young runner plants were often injured.

An analysis of the results of these researches led to certain practical suggestions for decreasing injury from heat. Early runners should be encouraged because their new roots have a better chance to penetrate the soil before the extremely high temperatures set in. Mulching the beds lightly after the early runners have rooted tends to protect them from direct sunlight and to lower the temperature of the soil surface. Frequent irrigation of strawberry beds during midsummer tends to lower soil temperatures and thus decrease the plant losses.

Oklahoma is not one of the larger strawberry producing States; it ranks about twelfth among the 15 leading midspring producing States according to the average acreage over the 10-year period, 1934 to 1943. The strawberry is, however, a very important fruit for farm and urban use and these researches, which help to make its culture possible under adverse conditions, will mean a great deal to the people of Oklahoma as well as of nearby States.

BETTER VEGETABLES FOR THE CONSUMER

Florida produces a tremendous quantity of vegetables for fresh-market use—a total of approximately 771,700 tons in 1945, according to information released by the Department. In tomatoes alone, the Florida winter and spring crops totaled something over 3,900,000 bushels in 1945. Unfortunately, tomatoes designed for distant shipments have to be harvested in the green-ripe stage, and, as a result, never attain the quality that develops in vine-ripened fruit.

Sweet corn, another important Florida crop, is harvested when mature but declines rapidly in quality during transit. Recognizing the

need for improvement in the handling of vegetables, the Florida station in 1941 initiated studies designed to aid the grower and shipper in getting their products to the consumer in better condition. Although the problems were not wholly solved in 1947, when the project was closed through loss of the leader, some very worthwhile results were obtained. Covering tomatoes and sweet corn with thin elastic transparent wrapping material which permits the slow passage of oxygen and respiration products such as carbon dioxide—the effective life of the vegetables was prolonged, both in transit and when placed in the stores for sale. As a result, tomatoes could be allowed to attain a riper condition on the vine; this meant better quality when reaching the consumer, and better quality in turn meant increased sales and thereby greater demands. Favorable results were also obtained with sweet corn which after husking was covered with an elastic wrapping material. Because of its transparency, the covering displays the product to the purchaser and at the same time keeps it clean and palatable. Thus consumer and grower alike have profited well from the results of these researches.

OVERWINTERED LETTUCE PRODUCES ABUNDANT SEED

Vegetable-seed production is an important and rapidly expanding industry in the irrigated valley of Utah and Idaho. Here the bright sunny days and comparatively cool nights of summer, along with the controlled water supply, combine to provide an ideal environment for growing and maturing the seeds of vegetables, flowers, and forage crops. The spring lettuce crop often proved hazardous in Utah because the seed failed to mature until late September, at which time fall rains often interfered seriously with harvesting. Working with the Department, the Utah station found that lettuce seed sown in Sepember gave rise to small plants that could successfully survive the winter and go on to produce abundant seed crops ready for harvest the following August. Although some winterkilling took place, this was offset by planting extra seed and thinning out the plants in spring. Records taken at Farmington, Utah, in 1946 showed that overwintered lettuce produced more seed than did the spring-planted crops; in the Imperial 44 variety, the yields were 257 and 136 pounds per acre, respectively. These figures were for 1 year only, but the indications are that similar results may be regularly anticipated.

An interesting side light was observed on certain plots where marketable heads were removed in early spring; the decapitated plants went on to produce nearly as much, and in one stance, more seed than did plants whose heads were simply split open to allow unobstructed development of the seedstalk. Thus, the grower might conceivably supplement his income from seed by selling fresh lettuce in the spring.

LIME INCREASES TOMATO YIELDS

The tomato has rapidly become one of the leading American vegetables. In the year 1945, 270,970 acres were harvested for the fresh market and 553,100 acres for processing. The farm value of the total commercial crop was estimated at nearly 180 million dollars. In addition, thousands of acres that could not be accounted for were grown in home gardens. Thus any cultural treatment that appreciably increases the yields becomes highly important.

In experiments conducted by the New York State station at Geneva, applications of ground limestone to tomatoes growing on a highly acid soil increased the yields to a marked degree. During the first year in which limestone was applied, the crop was increased by 4.2 tons an acre above that of comparably fertilized but unlimed areas. Thus under the prevailing conditions, with limestone costing about $21 per acre and the crop increase valued at $105 per acre, a handsome profit was returned to the grower. The station anticipates that the beneficial effect of lime treatment will continue for at least 3 or 4 years; this should exert a favorable influence not only on tomatoes but on other crops as well, including soil-improving plants introduced into the rotation.

ARSENIC-LADEN SOILS RESTORED TO PRODUCTIVITY

The problem of what to do with some 15,000 acres of former orchard lands which would not produce profitable crops was the problem offered the Washington station in 1940 by the discouraged owners. Years of heavy spraying with arsenicals to control codling moth had apparently left a toxic deposit of arsenic in the soil. As a result, many vegetables, grains, and small fruits would not grow or were so grievously stunted that they failed to produce worth-while crops. This was on inherently productive land located on favorable sites and provided with water rights. Taxes were high and something had to be done quickly to save the owners from loss of their properties.

The Washington station workers began at once to test a large variety of plants to determine whether some kinds might be tolerant to arsenic; in addition, they tried various cultural treatments such as plowing under large amounts of stable manure in an attempt to find a practical solution of the residue problem. Fortunately, marked differences were found in the capacity of various plants to grow in the presence of arsenic. Asparagus, potatoes, tomatoes, carrots, dewberries, red raspberries, and grapes were among the more tolerant plants, whereas snap beans, lima beans, onions, peas, and cucumbers were severely injured. Among grains, winter rye was resistant to arsenic and when plowed under in the green state rendered the soil more favorable to other crops. The character of the soil also proved important, with less injury to any given crop occurring on heavy soil than on light sands.

As a net result of these studies, many hundreds of acres were restored to a productive status, enabling the owners again to grow profitable crops. The initial objectives of the problem were solved and the project closed in 1947 to be replaced by a more technical study of the affected soil itself. In the new project, the possibility of treating the soil with chemicals that may convert the arsenic residue into harmless compounds will be explored in both laboratory and field. In the interim, the practical findings obtained by cut-and-try field methods saved the growers from loss of their properties.

PROGRESS IN PLANT-DISEASE RESEARCH

More than a million and a half dollars went into experiment station research on plant diseases and their control in the United States during the fiscal year 1946–47. Of this sum a little over one-fourth came from Federal grants, the States themselves putting up nearly three

times as much from their own funds. This, however, does not represent all the money spent by these institutions in applying weapons of science against diseases that plague the farmers' crops. For the most part, it covers only those expenditures for research carried on by trained pathologists, but not the cost of work by plant breeders in solving plant-disease problems by development of crop varieties resistant or tolerant to particular infections. Neither does it include the expense incurred by agronomists in working out systems of rotation and soil management to reduce the losses from soil-borne parasites.

The tremendous volume of 1946 harvests in America, which stood between countless human beings and starvation, was made possible in part by the effective methods of plant-disease control devised by scientific research and more than ever before put into general use by American farmers. Returns on the public investment in plant disease research were especially conspicuous. In spite of all the progress in control, however, certain crops suffered considerable losses during the past season from sweeping outbreaks of disease which farmers were inadequately prepared to meet and from disorders for which effective or economically practicable means of control had not yet been devised.

Emphasis in experiment station research on plant disease problems during the year has varied with the area and the crop concerned. In all States much attention was given to experimental work aiming to determine the comparative value and economy of a wide range of newer synthetic fungicides for use as sprays, dusts, or seed treatments on various crops grown under differing soil and climatic conditions throughout the country.

A striking example of the spirit of cooperation among technical workers that is speeding up the service of science to agriculture is shown in the willingness of plant pathologists to plan experiments together where feasible and to pool the results of their current trials of the newer fungicides. Under a volunteer committee of experiment station and Department specialists, the general findings among the fungicide tests of the 1946 season contributed by 160 plant pathologists in 38 States and 7 Canadian provinces were summarized in mimeographed form and made available to the cooperating workers. This summary has proved widely useful in tentatively evaluating the different materials used under varied conditions and in planning future experimental and extension programs. This report included results secured with 118 different fungicides or their combinations, a number of which were given general field tests in different areas for the first time.

Continued activity was directed to the perplexing problems created by virus diseases of plants. In this connection it was found that some of the newer insecticides, such as DDT, promise to reduce the spread of certain damaging viruses through control of the insects that carry them. New disorders were also investigated as to cause, importance, and possible means of prevention.

Increased investigational work was conducted in many localities where plant nematodes infest the soil to compare the effectiveness of new soil fumigants and other treatments in reducing their attacks on many crops, to determine their relative costs, and to learn how best to apply them under different conditions.

Further progress was evident in the laborious testing of crop varieties and parent lines in the search for heritable resistance to various disease-producing fungi and their biological races. The accumulating results of this work promise to add to the list of disease-resistant lines available to growers of important crops.

A more intensive and widespread attack was made on problems created by the soil-borne plant diseases that year after year are responsible for perhaps the largest total reduction in crop yields. Efforts were thus made to learn more about the organisms involved and the conditions favorable or unfavorable to their increase or decrease, as a prerequisite to finding better means of preventing such insidious diseases as the seedling blights, root rots, stem rots, and wilts, that proved to be among the most difficult types of plant disorders to investigate and for which to devise practicable methods of control.

Plant pathologists in a number of States continued to cooperate in carrying forward forecasting and warning services for several important crop diseases. This important type of aid to agriculture is fortunately to be assured greater permanence through the setting up of a national State-Federal program under the Research and Marketing Act of 1946; in this cooperative effort the Department serves as a clearing house and distributing center for timely information on certain diseases that often assume epidemic proportions.

Some examples of the results of particular efforts in plant disease research, supported by Federal grants, that have been brought to successful completion during the year, are presented in the following pages. These, however, represent but a small fraction of the current achievements in this field from which agriculture will benefit.

ULTRAVIOLET RAYS DETECT POTATO RING ROT

Time has fully justified the apprehension of American potato growers over the invasion of this country by the bacterial ring rot. Had it not been for the prompt mobilization of the plant pathologists in an intensive research program on the disease and on methods of preventing it, this malady might have developed into the most destructive plague of potatoes ever experienced in the United States. The full scope of the investigations that enabled the disease to be held in check throughout the country is too great to be reported upon here. However, the phases undertaken by the Montana station under Federal-grant funds in 1940 and closed during the past year will serve to illustrate the way in which science is directed by the experiment stations against such problems as are continually arising in many branches of agriculture.

Ring rot, long known as a rather destructive disease in Europe, was first reported in this country from Maine in 1934. No one knew whether or not it would prove equally troublesome in the United States. Moreover no one knew what to do about it. It could not be controlled by spraying. It was often carried undetected in seed potatoes that looked healthy on the outside. It spread amazingly fast. Within 5 years it had been reported from at least 20 States stretching from coast to coast and from Canada to the Gulf of Mexico. The Department with a number of experiment stations began a coordinated

program to study the disease. Ring rot proved exceedingly destructive when allowed to become rampant; it was also highly infectious and easily spread by the cutting knife and by sacks or other equipment previously in contact with diseased tubers.

The one most encouraging contribution from this joint research was the discovery that the bacterial parasite fails to live over winter in the soil where a diseased crop has grown and cannot thus be transferred to the next crop planted on the same land. This meant that if the owner of a potato farm where the disease had appeared were able to obtain completely disease-free seed, he could go on raising healthy potatoes—provided, of course, he did not allow any lingering contamination to come in contact with his healthy seed tubers. The problem remained of finding how to make sure that a particular seed stock was free from infection.

Montana is an important source of high-quality potato seed stocks. Seed certification services insisted that certification should be denied fields where ring rot was present. This appeared to be the major protection available to American potato growers against uncontrolled spread of the disease. How to insure maintenance of ring rot free potato stocks was the difficult question confronting the Montana potato seed producers. They took the problem to the State experiment station after the disease had appeared in most of their potato-growing areas and had resulted in serious losses to some of the growers.

Clearly the key to holding the disease in check was to find a speedy, practicable, and reliable method of determining whether the disease was present in any particular seed stock in order that diseased stocks might be discarded and only healthy ones planted. This the Montana station undertook to do. The method of detecting the presence of ring rot bacteria employed at that time by plant pathologists was a time-consuming staining method followed by microscopical examination of material from the cut surface of suspected tubers.

Workers at the Montana station found that under the invisible rays from an ultraviolet lamp shining on the surface of a cut tuber, areas where ring rot bacteria were located showed a distinctive fluorescent glow. Intensive research was then begun to determine how reliable this test might be in comparison with the older techniques, to learn what conditions were necessary for successful use of the so-called black light, and to obtain information on the practical value of the method by growing tubers selected by its aid in field plots and rechecking field results in greenhouse trials the ensuing winter.

This investigation has now demonstrated that of all available sources of ultraviolet radiation tried, the H–4 lamp is most satisfactory for quick examination and at the same time is as effective as the slower staining method for detecting the ring rot bacteria. It has also shown that before testing under the ultraviolet lamp, tubers should be stored for a few days at 60° to 70° F. and then brought to temperatures of 36° to 40° to give the clearest detection. During the course of the study thousands of tubers were tested from seed stocks carrying various amounts of infection and the accuracy of elimination by this means was checked annually through field and greenhouse plantings. The results consistently verified the high accuracy of this practical and inexpensive procedure.

Methods of preventing accidental transfer of infection from diseased to healthy tubers by knives used in cutting the seed pieces were also tried out. In accordance with results from other stations, the use of an automatically disinfected rotary cutting knife was found exceedingly effective in preventing this way of spreading the disease.

A large percentage of Montana seed potato growers are reported to have adopted the ultraviolet method for checking their seed stocks for ring rot, and growers in other States are also accepting the practice. Thus bacterial ring rot—one of the greatest menaces ever faced by the American potato industry—is being reduced to the role of a minor cause of loss through methods developed by research, and growers are now being provided with seed stocks free from the disease.

TOBACCO DISEASE RESEARCH

For a number of years now the Virginia station has directed research at several important diseases of tobacco. When the work was started not enough was known to provide the growers with satisfactory control measures. The picture today is far different. Tobacco farmers are now benefitting materially from the preventive methods devised and tested out by the station.

In 1928 the Virginia station began research under a Federal grant to investigate the virus disease known as ring spot. About a decade earlier this disorder had been recognized by the station workers as a distinct disease. Following this discovery they found that the virus could be transmitted to plants of many botanical families and that insects could carry it. Effective control could not be put into effect, however, without more information about the virus itself. These workers therefore set out to learn where ring spot occurred in the State, how it survived the winter, and how it was being spread in the field.

In 1937 the scope of the undertaking was expanded to include the tobacco mosaic virus, which was present in all tobacco-growing areas of the State. Every year it reduced the value of the crop by 1 to 3 percent, but was more prevalent and severe in some localities than in others. The task was to learn why. At the same time, the station began a program of tobacco breeding to develop, if possible, varieties that would be resistant to these viruses and at the same time adapted to Virginia conditions.

Virus diseases were not the only tobacco maladies causing heavy yearly losses in Virginia. Black root rot caused by the soil-borne fungus, *Thielaviopsis basicola*, was troublesome in many localities and satisfactory ways to reduce the infection were lacking. In fact, current soil-liming practices in some areas had even increased the root rot problem. Hence, in 1934, because no other satisfactory method of control had been worked out, the station initiated a long-time program to discover sources of resistance to the disease and to breed for adapted resistant line of both bright and dark tobaccos.

Available funds and staff limited the work to these tobacco-disease problems until 1943, when additional funds were provided for studying two other serious soil-borne diseases, namely, black shank, caused by the fungus, *Phytophthora parasitica* var. *nicotianae*, and Granville wilt, caused by the bacterium, *Phytomonas solanacearum*.

Black shank probably invaded Virginia about 1937. By 1942 it was causing serious damage in at least three counties and on some farms was responsible for a total loss of the tobacco crop. Although the fungus could not be eradicated in Florida, where the disease first appeared, the experiment station there had saved the shade-grown tobacco industry by developing satisfactory black-shank resistant strains; these, however, were not adapted to Virginia. Furthermore, all the Virginia flue-cured types grown at the time were susceptible. The Virginia station therefore undertook a program of selection and breeding in the hope of obtaining locally adapted resistant varieties.

The bacterial wilt, first recognized in tobacco during 1903 in Granville County, N. C., had spread into Virginia where it often caused heavy losses in some localities. The North Carolina station had shown that no types of tobacco then available were resistant enough to be satisfactory in infested soils and that chemical treatment of the soil was impractical. Certain crop rotations had proved helpful but various other crops and weeds were found also subject to attack and kept the disease going. Would it be possible to find resistance? The Virginia station set out on this search.

In 1947 the station brought these separate research efforts to a close. Work on tobacco-disease problems was not discontinued, however, for the station has now launched a comprehensive long-time tobacco-breeding program aiming to combine, in varieties of both dark and light tobacco, resistance to as many diseases as possible. At the same time fundamental studies have been started to learn the influence of changing soil conditions and various methods of soil sterilization on the soil-borne parasites of this crop.

During the progess of the researches thus superseded many facts were brought out that have had great practical value as well as scientific importance. At least a half dozen publications of one type or another have passed the accumulated information on to growers and to scientific workers interested in similar problems. More important still, is what the growers have done with the information thus made available. One helpful contribution from this work was the discovery that ring spot virus generally originates in clover or alfalfa fields and spreads to tobacco. Growers now avoid much ring spot infection by not planting tobacco after these crops or close to them. The Virginia station finding that flue-curing often fails to destroy mosaic virus led many growers to avoid the personal use of tobacco while working with tobacco plants; in this way much accidental infection was prevented. More significant, however, are the promising mosaic-resistant lines of tobacco that have been developed by the station and are now being tested out for yield and quality in various parts of the State before their release.

The study of black root rot showed that the disease can hardly be controlled by crop rotation or culture methods, although it is less severe on the more acid soils and where legumes have not been grown. Resistance to the disease, however, was found in different types of tobacco. The discovery, testing, and introduction in 1942 of the Yellow Special variety of flue-cured tobacco, which carries a degree of resistance, was a major accomplishment as shown by the fact that some 25,000 acres are now planted each year to this variety. On most Virginia soils it yields 100 pounds more per acre than former varieties,

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bringing an additional $800,000 income to farmers at 1946 prices. Even more resistant types have been developed in the course of this work. These are now in widespread tests for yield and quality.

When it was discovered that Granville wilt and black shank could not be satisfactorily controlled by chemicals applied to the soil, the Virginia station turned to a program of breeding for resistance. Beginning with 364 hybrid field selections, three different types of flue-cured tobaccos have been developed that are highly resistant to black shank and highly tolerant to certain other root diseases. They are also exceptionally good in quality and several strains have yielded over 1,500 pounds per acre on soil so badly infested as to prevent the growing of ordinary varieties. A strain of tobacco resistant to Granville wilt has also been secured. Under the future program of the station an effort will be made to combine this with different types of tobaccos resistant to black shank and other diseases. In 1947 enough seed of black shank-resistant strains was released to produce more than 200,000,000 pounds of tobacco when cured. Growers who faced losses from black shank ranging from 50 to 90 percent in 1946 can now look to these new types to save them from such calamities in the future.

CORN SEED TREATMENT

With the coming of hybrid corn into general use corn-seed treatment became generally adopted in the so-called Corn Belt. Experiments conducted in this area by the experiment stations, in which a number cooperated, proved the value of certain chemicals applied to the seed for reducing losses in seedling stands, particularly when soil conditions were unfavorable for prompt and vigorous germination. The fungicide on the surface of the seed acted to protect the young sprouts from attack by the seed-borne and soil-borne organisms that can injure the seed, or cause root rot or seedling blight. With first-class seed and good soil and weather conditions at planting time no particular benefit often accrued but with seed of poor grade, seed injured in threshing, or seed put in when the soil was cold and wet, the benefits were often marked. In Corn Belt soils with locally adapted varieties, no indication of injury from the recommended seed treatment was observed. Moreover, the cost was small and provided manifestly good insurance.

The next question to be answered was—How about seed treatment for corn grown in the southern half of the country? Would it be as safe and useful as it had proved to be for the Corn Belt? These were questions that nobody could answer. The only way to find out was through actual trials. There was a growing realization of the part played by plant diseases in contributing to low corn yields throughout the South. There was also a feeling that more rapid progress would be made in dealing with such problems if the experiment stations could coordinate their investigations and pool their results. Thus representatives from five southern States and the Department met in January 1943 in Knoxville, Tenn., and laid plans for southern cooperative corn-disease-research programs.

The major emphasis at the outset was placed on a series of uniform cooperative seed-treatment tests. These trials were continued for 3 years in widely separated locations throughout the South. Many varieties of corn and different soil types, planting dates, and tempera-

ture and moisture conditions were represented in the experiments, as well as different chemicals applied at various dosages. The results brought together each year and then analyzed for the entire period led to the conclusions that for the region as a whole: (1) Corn seed treatment in the South generally results in a 5- to 10-percent improvement in stand and as much as 20-percent or more under adverse conditions following planting; (2) treatment may frequently mean the difference between a satisfactory seeding and one that must be replanted or replaced by a substitute crop; and, (3) since weather after planting cannot be too accurately forecast and seed treatment is very inexpensive, corn-seed treatment should become a standard practice every year in the South, serving as a form of crop insurance.

The Arkansas station entered into this cooperative program by research studies now brought to a close. Through the aid of Federal-grant funds experiments were carried on at three different locations in the State. From year to year the results were made available to Arkansas farmers in various ways. At the end of the work a bulletin was published giving a summary of the experiments, with results from other States included for comparison. The evidence was clear that several good seed-treating materials were available. These included several new synthetic compounds, such as Spergon and Arasan, that had as a rule improved stands and yields by 5 to 10 percent in comparison with untreated corn in the plots. Dusting the grain with 1 ounce per bushel was held sufficient.

Already Arkansas agriculture has benefitted from this work. Practically all seed corn sold by commercial dealers in the State is now so treated. The resulting increased harvest of corn in Arkansas during 1946 has been conservatively estimated as no less than $355,000. Other States in the region are enjoying similar benefits from this simple scientific method of reducing the seedling losses which these cooperative trials demonstrated to be as useful throughout the South as they had been in the North.

POTATO SEED TREATMENTS

Since the National Potato Improvement Program started cooperatively some years ago by the Department and the State experiment stations, new varieties of superior quality and yielding ability have replaced the older standard sorts in many parts of the country. Experiments that were carried out in many States before the new varieties became available pointed to potato seed treatment as as desirable practice to help prevent two common diseases from being carried into new potato fields with the seed obtained from contaminated soils. These were the soil-borne scab and rhizoctonia diseases caused by micro-organisms that could be killed by dipping the seed potatoes into weak solutions of formaldehyde, mercuric chloride, or certain other materials. Such treatment was a well-established practice among the better growers at the time when the new varieties became available. Continued use of these same methods on the newer potatoes soon brought reports of failure to prevent scab or rhizoctonia as well as of damage to the seed pieces.

These complaints were becoming more numerous about the time when chemists and plant pathologists were bringing forth a number of promising new organic compounds that appeared to have unusual

fungicidal power and to cause less plant injury than older materials. Thus several experiment stations again opened up the question of seed treatment for potatoes. Comparative tests were made of the newer and older fungicidal materials, of the newer and older varieties of potatoes, and of new and old potato land. The conclusions were not altogether what had been expected, but potato farmers in many States are now saving considerable work and some money as a result.

A number of stations cooperated in experiments that have been referred to in an earlier report. To meet a local demand for further information the Massachusetts station in 1943 undertook, on Connecticut Valley soil, a series of tests that were recently concluded. In three seasons' work nine different treatments were tried out with seven important potato varieties commonly grown in the Bay State; the results for the different years were in strong agreement.

The standard mercuric chloride and formaldehyde treatments caused little or no injury to tubers of the old varieties Irish Cobbler, Green Mountain, and Russet Rural. They were, however, responsible for moderate injury to seedstock of the new varieties Katahdin, Earlaine, and Sebago and more severe injury to Chippewa potatoes, resulting in corresponding reductions in stand. Detrimental effects of the organic mercury treatments were also produced on stands of the four latter varieties.

The new synthetic chemicals, Fermate and Spergon, caused no injury either to tubers or stand in any of the varieties under trial. On the other hand, there was no evidence of improvement in plant vigor or of reduction in rhizoctonia infection from the use of these or any of the other treatments employed. Moreover, although scab was not a problem in the soil where these tests were conducted, recent experiments in other States have shown little evidence of benefit from tuber treatment against this disease where the organism was already active in the soil.

The conclusion to be drawn from these Massachusetts station investigations, as presented in recent annual reports, agrees with that arrived at in other States, namely, that for growers of table potatoes treatment of planting stock is usually not a profitable procedure even with the newer less injurious treatments, whereas the older treatments are definitely injurious to stands when applied to a number of the best new varieties. This is not to say that situations may not exist where some form of seed treatment would be desirable—for example, where fusarial seed-piece rot is a problem. It does mean, however, that in many established potato areas, growers are justified in omitting the time-consuming job of seed treatment. This will also save them the out-of-pocket costs as well as possible injury to the more sensitive varieties.

NEW SPRAYS AND DUSTS FOR FRUIT

So many experiment stations are engaged in trying out sprays on different kinds of fruit that it is easy to assume unnecessary duplication in this field of research. At the present time, in fact, there is an energetic revival of fungicidal tests in all parts of the country; in these tests, however, practically no actual duplication exists. Such renewed activity is necessary and important to fruit growers everywhere. Chemists working with plant pathologists have developed a

promising series of new protective chemicals that must be tried out with impartial scientific thoroughness before it is safe for growers to place their trust in them.

This program of experimentation is necessarily laborious and complicated and, in justice to its own fruit raisers, every State must participate. Past experience has proved that for each fruit district the program of protection that works best against the local diseases is almost certain to differ from that of any other fruit district, even within the borders of the same State. This situation is explainable through differences in soil, temperature, rainfall, and length of growing season, differences in the varieties and types of fruit grown, and through differences in the particular diseases present or variations in the way they act in response to local environments.

Few except the scientists engaged in such work realize the multitude of factors influencing the effectiveness of a fungicide against diseases of various kinds or rendering it harmful to the plant it is designed to protect. To find out how a new fungicide will meet local needs in comparison with an older standard fungicide or to determine how best it will fit into the fruit-protection program of a particular locality, the new material must be tried out for several years to observe the effects of the different environments. It must also be tested out in various strengths and combinations and at different times of application. Watch must be kept on the weather conditions and the incidence of diseases for each season, and the waves of infection must be timed. Records must be made of the amount of disease, the extent of loss sustained, and the degree of fungicidal injury met with in each experimental plot. Besides all this, the cost of materials, equipment, and labor must be estimated and compared with the value of the returns.

It is thus readily seen that the task of evaluating a new fungicide is neither short nor easy. It is a job that no fruit grower, however capable, can afford to undertake for himself. He has to depend upon his experiment station to carry out the necessary technical studies and give him the detailed results for guidance.

As an example of this type of station research, from which growers are already reaping benefit, attention is called to an investigation of new sprays begun in 1943 by the Missouri station and now merged with related studies in a research program of greater scope.

During the four seasons covered by this study the station determined that for apple orchards under Missouri conditions the new synthetic compound Puratized Agricultural Spray (phenyl triethanol ammonium lactate) surpassed lime-sulfur—the previous standard material—in early season scab control and without injurious effect produced on the trees by lime-sulfur. For cedar-apple rust, Fermate (ferric dimethl dithiocarbamate) surpassed all other materials investigated. This fungicide also proved equal to the best wettable sulfurs for scab control and to bordeaux for preventing apple blotch; it could also be applied without the severe injuries to fruit and foliage caused by the bordeaux. Several other new materials were tried out but proved less successful.

For cherry leaf spot control, Fermate as well as Methasan (zinc dimethyl dithiocarbamate) proved effective early in the season and produced little or no injury to the leaves or fruit. For after-harvest spraying, bordeaux was the most effective protectant tested. The use

of Omilite (polyethylene polysulfide) with Fermate gave such promise in a 1-year test that it is to be tried out further as a possible all-season spray for cherries.

For grape black rot Fermate was fully effective, giving no such injury as the standard bordeaux spray formerly used. Puratized and Methasan, although effective, caused some injury.

Anthracnose, a serious disease on raspberries, has been difficult to combat in the past but was well controlled with lime-sulfur applied at the time the leaf buds swell, followed by Fermate for the summer sprays. Fermate caused no such injury during the warm weather of summer as often results from the use of lime-sulfur.

From time to time during the course of these experiments the growers were kept informed of progress by the publication of results in the proceedings of State horticultural societies and in special circulars as well as through other channels. Moreover, those who have followed the guidance of the experiment stations on the use of these newer fungicides are experiencing excellent control of diseases along with reductions in the amount of injury formerly sustained from treatment with some of the older materials.

PINK ROOT AND BULB ROT OF ONION

With the development by the New Mexico station of the Early Grano variety of sweet Spanish or Valencia type of onion, which has met with considerable success in New Mexico and nearby areas, a heavy demand arose for the seed. This led to a program of experimentation to determine the best practices for profitable seed production. In the course of these experiments it became evident that the growing of this type of onion, either for bulbs or for seed, was hampered by plant diseases and certain other troubles.

Preliminary investigations were therefore begun by the New Mexico station in 1938 under Federal-grant fund support to lay a basis for reducing the damage from diseases. These studies were completed during the past year and a bulletin recording the results has been in preparation.

At the time these researches began, the principal maladies affecting onions grown for seed in New Mexico were those known as pink root, bulb rot, and false blight. A lack of agreement as to their causes among investigators elsewhere made it necessary to undertake detailed microscopic examinations along with laboratory culture and inoculation work to settle these questions. Only when the cause of a disease is known can preventive measures be intelligently devised.

Long hard work brought out the true situation. These researches finally demonstrated that the so-called false blight is only one of the effects of the pink root rot. The bulb rot occurring in storage proved to be most serious in onions from crops affected with pink root rot. Moreover, the pink root was generally associated with the presence of two soil-inhabiting fungi, *Phoma terristris* and *Fusarium zonatum*. The former was found to cause the initial injury to the roots; the latter, working best at somewhat higher temperatures, then entered and increased the injury. The fusarium was responsible for rotting of the bulbs both in the field and in storage.

With the establishment of this causal sequence, the problem of preventing or reducing the damage caused by these two fungi was at-

tacked. Various chemicals were used to treat either the onion seedlings or the soil; some apparently caused injury and reduced yields. Changing the acidity or alkalinity of the soil within practical limits gave no promise of eliminating either fungus. A soil fumigant, D–D mixture, was found ineffective against the pink root fungus; on the other hand, tear gas (chloropicrin) applied in the same way markedly reduced or eliminated infection both in greenhouse tests and in the field. The high cost of soil treatment, however, limits its use on a large scale. Hence attention was then turned to selection and breeding as a means of developing resistant strains of the desired type of onions. A start has already been made and, with encouragement from the results of work elsewhere, future research is likely to be directed toward that end.

VIRUS DISEASES OF PAPAYA

A few yeas ago increasing demands for papayas grown in Puerto Rico for sale as fresh fruit, for use in preserves, and for extraction of the enzyme papain indicated that production of this fruit could become a highly profitable enterprise. In view of the losses sustained from virus diseases, however, serious doubt arose as to whether it would be possible to expand the growing of this tree on the Island. Already virus infection had caused the death of a large porportion of the papaya trees under observation at the Isabella substation. It was at least apparent that production could not be successfully increased until ways were found to keep these diseases under control.

In 1940, therefore, the Puerto Rico University station undertook to obtain a better understanding of these diseases and the ways in which they are transmitted; without such knowledge but little progress could be expected in developing effective means of prevention or control. The research work started at that time has brought forth much information of value and pointed the direction in which practical control may be sought. In the course of these investigations the Rockefeller Institute for Medical Research, through its division of plant pathology, rendered important assistance, sending one of its specialists in plant viruses to work for a time with the station staff.

The major results of this work have been to clarify the papaya virus disease situation in Puerto Rico. Two viruses were found to be at work. The most important and prevalent of them is the one causing bunchy top, a disease capable of spread only by means of the leafhopper, *Empoasca papayae*. The other is the papaya mosaic disease, found only in a limited area of the southern coastal region. It was learned that this disease is readily transmitted by mechanical means and that its natural insect carrier was the green citrus aphid, *Aphis spiraecola*.

The distinguishing symptoms and characteristics of these diseases were determined by careful study. Of all the varieties of papaya and species of related plants tested, none was found resistant to either virus except *Carica monoica*, a plant native to the Andes which seemed to be resistant to mosaic virus alone. Unfortunately all efforts to transfer this resistance by crossing the wild plant with cultivated papaya have thus far proved unsuccessful.

In view of the lack of success in obtaining resistance to either virus in papaya, attention was directed to the use of chemical methods

of control. Initial experiments indicated that the new insecticide, DDT, through its destruction of the insect carrier, is almost certain to become a valuable asset against buchy top but is apparently inadequate to control the spread of papaya mosaic.

Six scientific papers report the results of these researches. Future control work will be conducted by entomologists in an effort to find the best program for use against the insect carriers. This is the most promising approach now in sight for the solution of these problems.

VIRUS WILT OF POTATO

A disease of potatoes reported in West Virginia as early as 1931 was recognized to be unlike any previously described malady affecting this crop. As time passed this disease—sometimes called purpletop wilt—became more extensive and destructive both in West Virginia and in Pennsylvania, but was most serious at elevations of 1,000 feet or higher. By 1936 it was destroying at least 25 percent of the crop in some localities, with losses reaching as high as 75 percent on certain individual farms. The cause was unknown and general observations had shed but little light on where it came from or how to get rid of it.

At this point the West Virginia station began to investigate. Preliminary studies suggested that it was an infection brought into potato fields by insects after the plants were in bloom but that it was not caused by either fungi or bacteria. This led the station in 1937 to undertake a thorough investigation of the problem and of possible ways of dealing with it. After 10 years this work has now drawn to a close with publication of a comprehensive bulletin presenting the results and summarizing the known facts about the disease and possible means for its control. During the course of these studies, five articles in scientific or technical journals had also conveyed reports of progress in the research to those most directly concerned.

It appears from investigations in other States that purpletop wilt or bluestem occurs most abundantly in the region from New York to North Dakota and that it is rather widespread in the northern and eastern regions of the United States where it has often been unrecognized or confused with other disorders. It has not been reported as important in the South or the Far West. The alarm arising from fears that this disease might become a major obstacle to production in the important potato areas of the country has largely disappeared as a result of facts brought out by the research under discussion. Although the disease is one that may be expected to remain as a sporadic or minor source of loss here and there, newer spraying and dusting materials employed in the major potato-growing areas promise to hold it in check through control of the insects responsible for its spread.

In brief, the West Virginia investigations appear to have established the following pertinent and worthwhile information. Purpletop wilt or bluestem is caused by a virus. This virus is never spread from one potato plant to another, nor is it perpetuated like other potato viruses through the tubers produced on infected plants. This is most fortunate for the grower, since he need not fear introduction of the disease through his seed stocks. Furthermore, since the virus is not transmissible through the tubers, officials need not eliminate from certification those fields of seed potatoes containing only small amounts of infection. Neither can the disease be spread by men in cutting or

handling the seed tubers, in cultivating the plants, or in harvesting or storing the crop.

In other words, the damage from purpletop wilt is limited to the reduced yields and internal browning of tubers from plants infected as they grow in the field, and to the reduced yields from plants grown the following season from tubers developed on such infected plants. The losses in yield from early current-season infection may reach as high as 50 percent for individual plants, but the objectionable tuber discoloration may in some cases be even more serious than the reductions in yield. Crop losses from this disease appear, however, to be mostly light and scattered.

In these studies evidence was developed that the virus involved is identical with the one long recognized as causing much damage to asters, carrots, lettuce, and many other plants, and known under the name of aster yellow virus. It is transmitted to potato by the aster leafhopper. This insect, however, does not breed naturally on the potato and is apparently unable to spread the virus from one potato plant to another. It picks up the yellows virus from other plants on which it feeds outside the potato fields and when forced to migrate into potato fields brings the virus with it and inoculates the potato plants when puncturing them to feed on the juices.

A good many days are required before any symptoms become visible, and this incubation period is longer in the potato than in asters and some other plants. Although it causes damage to the potato plant infected, the virus seems to lose its infectivity promptly within the tissues of this particular host.

Because of the nature of this disease, an actual cure seems hardly possible. Since fungicidal sprays in general do not effectively repel the insect that spreads it, this form of protection is of no avail. Some reduction in the amount of infection has been secured experimentally, however, by spraying or dusting potato fields with DDT. Although this insecticide is very potent against leafhoppers complete control by this method cannot be expected, since the virus-bearing insect invaders will almost certainly cause some infection before they are killed. The final solution of the problem may lie in finding the local sources from which the overwintered virus and insects come and applying community measures to prevent the building up of infective populations of leafhoppers through use of some such insecticide as DDT.

The Idaho station has shown that aster yellows, which once threatened to destroy the Idaho carrot seed industry, can be largely prevented in this crop by growing the stecklings at a safe distance from any seed-producing fields where yellows virus is present. Perhaps the same principle can be adapted in some way to the potato-growing areas where purpletop wilt is a recurring local hazard. In any case, the research provides good evidence that substitution of early for late varieties of potatoes will greatly reduce the losses in such areas.

SUGAR-BEET SEEDLING BLIGHT

Sugar beets gave early promise of becoming an exceedingly profitable crop for a number of irrigated areas of the northern Great Plains. As one year succeeded another, however, it became apparent that in some areas the yields were going downhill and rapidly attaining an unprofitable level. On going into their fields the farmers often found

associated with this drop in production a trouble which they called "black root" or seedling blight; this condition was responsible for much of the reduction in stands and yields. The State experiment stations in these areas were soon called into action to find out more about the origin and nature of this type of root rot and blight and to learn what could be done to check its apparently increasing destructiveness.

The South Dakota station was among the first to take hold of this problem. Its program of research began in 1942 with a special comparison of the damage to sugar beets in the various rotation plots that had been running for many years at the Department's Belle Fourche Experiment Station. The seedling blight studies continued for 5 years.

During this period the first important disclosure was that a single species of fungus was responsible for the major losses in this area. It was a soil-inhabiting form, *Aphanomyces cochlioides*, which attacked the seedlings with especial vigor in rotations where alfalfa had immediately preceded the planting of sugar beets; it was also abundant in rotations where clover had been the preceding crop. Wherever beets were grown continuously this fungus was also prevalent unless heavy applications of manure had been made each year.

Already much benefit has resulted from following the practices shown by these investigations to be most successful in suppressing the black root rot type of seedling damage on irrigated soils. These helpful procedures include rotations in which nonleguminous crops precede sugar beets, together with annual applications of manure. Control by these practices is not sufficiently complete, however, to consider them as the final solution for the problem. The development by breeding of varieties of sugar beets adapted to local soils and climate and highly resistant or immune to *Aphanomyces* would appear to be an approach well worth following in future research.

VARIABILITY IN DISEASES OF TOMATOES

Certain disagreeable facts in nature cannot be dodged if agriculture is to rest on a sound basis. When, some years ago, scientists began intensive studies of the kinds of micro-organisms that induce infectious diseases in plants the disheartening discovery was made that the characteristics of the agents causing many important diseases varied, that there were often several or many strains or "biological races" involved, and that resistance or immunity to one form did not necessarily involve resistance to other forms of the same pathogen. The longer research workers delved into this problem of biological or physiological variation in disease-producing organisms, the more evidence was accumulated that such variability is the usual thing rather than a rare occurrence and that recognition of this fact is essential to successful agricultural progress.

Much credit goes to the Minnesota station, along with the advanced students working there, for building up over the years a mass of scientific data on this subject. This research proved that failure of important rust- and smut-resistant varieties of cereals to hold their resistance permanently could be explained on the basis of this kind of variation. It pointed out also that the factor of variability in pathogenic organisms must always tbe taken into account in any program of scientific plant breeding.

Today experiment stations in many parts of the United States and the Department are studying the extent and nature of the variation existing in many kinds of fungi, bacteria, and viruses that can parasitize our major crop plants. Much time is devoted to the isolation of specialized strains and to their use in measuring the resistance of innumerable varieties of the principal crop plants and their wild relatives from all parts of the world. These activities are undertaken because of the realization that only through such efforts can a proper foundation be laid for the synthesis of new crop varieties and hybrids possessing disease resistance of broader scope and greater permanence than their predecessors.

With these considerations in mind Indiana station workers decided in 1941 to begin a study of variability in the infectious agents responsible for some of the most important diseases attacking tomatoes. The station had good reason to undertake such an investigation because Indiana ranks high among the States in tomato production, sometimes devoting more than 100,000 acres to this crop. Moreover, diseases constitute one of the principal hazards of the industry, according to conservative estimates, reducing the value of the Indiana crop by at least 20 percent each year.

Among the most troublesome tomato diseases are those injuring the foliage, those attacking the fruit, and the soil-borne fusarium wilt. The wilt cannot be controlled by fungicides. A number of the other diseases can be held in check by sprays or dusts but only at considerable cost in labor, chemicals, and frequent damage to the vines. To meet this situation the experiment station is therefore directing its efforts toward the development of varieties resistant to as many of these diseases as possible and at the same time adapted to Indiana soils and climate.

In order to lay the necessary basis for a satisfactory program of this kind, a study was begun of the extent of variation occurring among tomato pathogens of major importance in the State, a subject on which there was little information. Although progress in this field was materially slowed down during the war by the diversion of two of the leaders to military service and the placing of emphasis on work of more immediate wartime importance, much significant information of value to the breeding program was developed during the life of this recently closed-out investigation.

Most important among the results was the discovery that in connection with fusarium wilt considerable variation in disease-producing ability occurred among the various strains of the fungus tested. These variants were tried out against a number of tomato strains possessing different types of wilt resistance. One type of resistance obtained from a relative of the common tomato was found to hold up against the most virulent of the fusarium races tested. Evidence was also secured that resistance to more than one fusarium strain may be combined in one line of wilt-resistant tomato. The investigation has yielded information of direct and immediate value to tomato breeders, whose work may be expected eventually to reduce the losses now sustained from wilt infections.

During the course of these studies variants were also found in a tomato virus, in the fungus causing early blight, and in a fungus responsible for the anthracnose type of fruit rot. The variability found proves the necessity for testing all tomato breeding stocks for

resistance to a wide range of races or strains of the different pathogens in order to avoid introducing varieties of limited disease resistance to the growers.

Although these studies are manifestly of a restricted and somewhat preliminary or exploratory character, as reported in the publications thus far issued, it is to be hoped that this type of research will be continued and expanded to meet more fully the needs of the breeders and growers of tomatoes.

PROGRESS ON THE SOUTHERN BLIGHT PROBLEM

In the warmer areas of the country, southern blight, caused by *Sclerotium rolfsii*, is responsible for serious losses of many kinds of plants in seedbed, garden, and field. In 1936 the Florida station undertook a limited investigation of the causal fungus in an effort to obtain needed information about the organism and its various forms which might explain the nature of susceptibility to its attacks and thus lay a foundation for better control.

The first approach was to get the fungus in pure culture from as many as possible of the different kinds of plants attacked and to test the strains obtained for differences in disease-producing ability. No evidence of this type of variation was found, since all forms of the fungus tested were equally capable of causing infection in the susceptible plants used. However, a long-sought stage of the fungus was at last discovered under natural conditions. The spores produced by this stage are projected into the air and may thus spread over long distances.

The work on preventive measures proved that for seedbeds, gardens, and similar situations crops can be raised on land infested with this fungus if the soil is drenched with ethyl mercury phosphate, 1 part to 25,000 parts of water. The cost of such treatment is so high, however, that its use will naturally be confined to seedbeds and especially valuable plantings. Other chemicals used as drenches were not as effective. It was hoped that soil treatments with dry chemicals might rid soils of the southern blight fungus, but trials with naphthalene, urea, and cyanamid failed to ward off infection.

Experiments were also performed to explore the possible use of heat for destroying the fungus of southern blight in infested ornamental plants. In these tests caladium corms were successfully sterilized without injury by soaking them in hot water for 30 minutes at a temperature of 122° F.; in the case of bulbs of the Tangier iris, temperatures high enough to kill the fungus also killed the plant.

This investigation admittedly failed to solve the whole problem of southern blight. Nevertheless it represents a worth-while contribution toward a better understanding of a very insidious, destructive, and erratic plant parasite and resulted in a procedure for dealing with infection from the soil by a plant-bed drench and a method of eradication by heat applicable to at least one kind of plant. Furthermore, enough information was obtained on the limitations of heat treatment to prevent growers from hastily trying the hot water method on all kinds of propagating material before further research has established the safety of the practice for individual species and varieties of plants.

POTATO PINK ROT

A type of potato rot sometimes known as "leak" was causing up to 20 percent loss in some Nebraska storage cellars at the time when the State experiment station was asked to learn the cause and how to cope with it under both storage and shipment conditions. Two kinds of soil molds—neither previously known to occur in Nebraska—were discovered in association with the trouble. One of them, *Phytophthora erythroseptica*, causes a wilt of the plant in the field as well as a pink rot of the tubers. The other, *P. drechsleri*, does no damage to the growing plant, these workers found, but causes a similar tuber rot after harvest and is favored by higher temperature than the other.

Nebraska potato growers have greatly reduced the extent of their losses from storage rots by following the preventive practices worked out under this investigation; namely, the avoidance of late irrigation, prompt marketing of the crop, and careful sorting of the tubers before shipping or storage. The study seems to indicate further that efforts to discover or develop resistant varieties may be warranted. A journal article and a bulletin have conveyed the results to the public in printed form.

NEW FUNGICIDES FOR CROP PROTECTION IN HAWAII

Recent work at the Hawaii station provides a good example of the kind of experimentation currently under way with new fungicidal materials to determine their usefulness for various crops under the conditions of disease and environment prevailing in widely different regions. Investigations by stations in other parts of the United States cannot be safely used as a guide by fruit and vegetable growers in the Islands, but the farmers of Hawaii, where plant diseases create a major problem, rightly expect to profit from advances in protectant chemicals as well as farmers on the mainland. The territorial station has recognized its responsibility to local growers and in recent years has been trying out many of the newer types of fungicides.

Among the more important findings already emerging from this work the following may be mentioned: The use of soil fumigation with D-D mixture has definitely increased vegetable yields through control of the root knot nematode at a cost for material far less than that for chloropicrin—the only satisfactory soil fumigant for nematode control known until 1943. Good results were secured by applying D-D either in a continuous band or by spot injection; it failed to give satisfactory control, however, when applied as an emulsion in the irrigation water.

White rust, at times a serious disease on oriental cabbage, was controlled effectively by either Yellow Cuprocide or wettable sulfur; on the other hand, the new organic compounds tested for this purpose proved far from satisfactory. Early blight and late blight of potato were effectively combated in the Islands by the use of Tri-Basic copper sulfate or Yellow Cuprocide. For powdery mildew on papaya foliage, wettable sulfur proved an excellent fungicide and Tri-Basic copper sulfate and Yellow Cuprocide gave fairly good results. For late blight and early blight of tomato, Zerlate, and Tri-Basic copper sulfate were the most effective among various fungicides tried out during 1947.

Probably of even greater significance in the long run is the Hawaii station's effort to find resistance to the various important vegetable

diseases occurring in the Islands. Already tomatoes resistant to the spotted wilt virus have been produced by the station and are now being grown extensively; promising tomato lines resistant to stemphylium gray leaf spot are also about ready for release. Nematode-resistant lines are now being sought and results are encouraging in this direction, although years may yet be required to reach the ultimate goal.

TOMATO AND POTATO LATE BLIGHT WARNING SERVICE

With the passing of the years it became more and more evident that the fight of the American farmer against plant diseases, even with the best weapons science could devise, would never attain maximum results without the aid of an effective Nation-wide plant disease information and forecasting service. Realization of this need, however, had brought relatively little substantial progress toward establishing such a service on anything like a permanent basis.

This was the situation up to 1946 when a practically unheralded epidemic of late blight brought sweeping damage to the American tomato crop and caused something like a $40,000,000 loss to the growers. The impact was just as great on the tomato-processing companies. The shock of this sudden destruction, coupled with the knowledge that growers who had sprayed properly and in time saved their own crops while neighbors were losing theirs, led to the calling of a conference at Indianapolis in November 1946. There the canners and scientists considered what might be done to prevent a recurrence of such a catastrophe to the production of our most important truck crop.

Previous efforts to develop an information service had not gone far enough. As mentioned in earlier reports, an emergency plant disease prevention organization was set up by the Department in cooperation with the States as a defense measure during World War II; this work was financed by special funds. Incidental to their major assignment the field men acquired considerable previously lacking information about the distribution of many preventable plant diseases and the extent of the losses which they caused. This information resulted in more effective efforts at control and helped maintain high wartime crop production in both field and garden. This service was discontinued, however, at the close of the war.

As a contribution to the war effort, pathologists in certain States had joined together to set up the beginnings of regional crop-disease information services. Working without sufficient funds or adequate Federal assistance these men voluntarily cooperated for several years in watching developments and reporting on the activity of cucurbit downy mildew along the Atlantic Coast and on the potato late blight in the upper Mississippi Valley. These data were sent to a key man who relayed summaries of the situation back to the particular States concerned. In this way, the growers were warned in time to forestall, through protective spraying, many thousands of dollars' worth of damage. Later, a similar cooperative tobacco blue mold information service was set up.

The tomato crop, however, had not been covered by these services. At the Indiana tomato-disease conference, therefore, action to provide this industry with such services was called for and the establishment of a far-flung late blight information or warning service for 1947 and thereafter was recommended. The Plant Science Technical Com-

mittee appointed by the directors of the experiment stations of the north central region at its meeting in Chicago in December 1946 urged that the Department cooperate with the States in developing a National plant disease information service. The American Phytopathological Society, representing the professional plant pathologists of the country, in the same month asked for more effective plant-disease reporting and forecasting.

As a result of these demands, it was made possible for the Plant Disease Survey of the Department, with the voluntary cooperation of plant pathologists in 32 States and the Dominion of Canada, to inaugurate such a service in respect to the phytophthora late blight of tomato and potato. Throughout the season, from the Mississippi Valley to the Atlantic Coast, key men in each State sent information on the progress of this disease to Washington, D. C. From there, every week or oftener a summary of the situation was despatched back to the cooperators. When any area appeared to be threatened with danger of an outbreak, local warnings by press and radio were at once issued to growers, along with advice as to the best preventive measure to meet local situations.

Never before had growers been so well prepared to stop a blight epidemic in its infancy. Although, in general the climatic conditions of 1947 did not favor the widespread damage of the previous season, blight activity was nevertheless reported in many sections of the large area surveyed. Evidence of the practical benefit of these timely forecasts and warnings was so clear that the States and the Department have set up under the new Research and Marketing Act an expanded cooperative service beginning with the fiscal year 1947–48 to include not only tomato and potato late blight, but also the downy mildew of cucumbers and melons and the downy mildew or blue mold of tobacco.

HOW FUNGICIDES ACT

In the past it has been necessary to proceed rather blindly in the search for new chemical compounds that might serve agriculture with better and safer protection against plant-disease infections. In more recent years thousands of chemicals have been tested by standard laboratory methods to determine whether or not they are effective in killing the spores of typical disease-producing fungi. Out of such laborious work have come a number of new fungicides with outstanding advantages over any previously used protective materials. Nobody, however, could tell precisely how they destroyed the power of spores to grow. Although thousands of ineffective or less valuable compounds have been discarded, in most instances very little information became available as to why they were inadequate in comparison with those that survived the screening tests.

It was logical to suppose that if it could be determined how various effective fungicides produce their results, it would then become possible to focus more intensive research on those whose chemical structure appeared to permit similar modes of action. In the long run greater returns might be excepted from such intelligently directed exploration. The Connecticut State station, aware of the force of these considerations, decided to undertake the difficult task of trying to find out how one series of effective new compounds actually did their work. These belong to the class of chemicals known as dithiocarbamates, which scientists at this station have been successful in developing.

The outcome of these efforts appears to represent a very significant step forward in the service of science to agriculture. The findings that grew out of 7 years of such intensive laboratory research have now been embodied in a recently published technical bulletin. This treatise may be expected to help materially in the future development of improved organic fungicides through the synthetic-chemistry approach. The value of this fundamental type of research is hard to estimate in dollars and cents. It must be recognized, however, that such work lays the groundwork for advances in crop protection that might otherwise be impossible.

The data presented in this bulletin cannot be reviewed in the limited space available, but certain of the outstanding conclusions should be mentioned. The evidence presented indicates two modes of fungicidal action in this class of compounds, namely: (1) The liberation of hydrogen sulfide, which is directly toxic to fungus spores and thus alters the spore proteins by addition of sulfhydryl groups; and (2) the formation of metal salts of the compound, which deprives the spores of certain trace metals needed in their vital activities. The improved fungicidal effect of adding zinc sulfate and lime to Dithane (disodium ethylene bisdithiocarbamate) was found to lie in the formation of the zinc salt of this compound in the presence of carbon dioxide. This salt on the exposed leaves of sprayed plants gave the mixture its added protective value. Manufacturers applying such information are now preparing zinc ethylene bisdithiocarbamate in the factory and many growers are using it as a more powerful protectant against fungus infections of plants.

REDUCING INSECT DAMAGE

The control of insect damage each year to crops, forests, domestic animals, and their products is a tremendous task, calling for the best effort of both research worker and layman. Great fluctuations in insect populations from year to year and place to place, ever increasing acreages of single crops in favorable sections, and introduction of new economic crops combine to provide an ever-changing situation with new problems constantly emerging. The recent discovery of powerful new insecticides and the development of new methods for applying them give much promise in this never-ending battle. In fact many control measures which a few years ago were only a distinct hope can now be developed into actual practices on the farm.

The State experiment stations as well as Department agencies have availed themselves of these new opportunties in insect control. Research workers have devoted much time and energy to the study of the new insecticides: How to use them most effectively and the reactions of insects and host plants to them. Much has been accomplished in a short time but many more questions remain yet to be answered. DDT, one of the most important of the new insecticidal discoveries, has been found highly effective for killing a large number of insect pests. Some species, however, are practically immune to this powerful chemical. Fortunately, other potent new insecticides may fill some of the gaps left by DDT in our defense against the insect pests. Further studies of the habits and structure of insects should, however, aid in explaining this selective action of insecticidal chemicals.

While the most outstanding advances in the immediate control of insects have been made with the newer insecticides—especially DDT—the improvements in control methods as developed by the experiment stations and the Department have also involved a number of other lines of attack. Although not as spectacular as the results achieved with DDT and other new materials, the reduction of insect damage by means other than insecticides, where practical, may in the long run prove to be of greater benefit to agriculture.

A few examples of the results of research in insect control by the State experiment stations are presented:

INSECTICIDES CONTROL SUGARCANE PESTS

Borers are one of the most serious handicaps to successful sugarcane production. In Louisiana, the annual damage in the 1946 season alone was estimated at approximately $3,000,000; this loss was about 8 percent of the value of the State's total surgarcane crop. The Louisiana station made a careful life history study of the borer and found that it spends most of its early life within the cane. This is a vital point because, while hidden within the plant tissues, the young borer is relatively safe from insecticidal treatments. Hence a method of control was sought that would kill the eggs or the newly hatched borers before they penetrated the canes. Attempts were also made to develop methods of killing the adult months, as well as the borers that occasionally come out of the cane to seek new feeding areas.

Among various materials tested, cryolite dust showed promise. Repeated tests in commercial fields over a 4-year period revealed cryolite to be effective in large-scale operations. As a result of these findings approximately 7,000 acres of the heaviest infested cane in Louisiana were dusted with this insecticide; the savings to these cane growers were estimated at around $300,000.

Another valuable result of this research on borer control was the correlation of infestation with injury. From these data it will be possible to estimate more accurately the damage at various levels of borer infestation and to determine areas justifying expenditures for dusting.

Concurrent with the tests of cryolite for borer control, other insecticides were also being tried out against surgarcane pests. The excellent control obtained with benezene hexachloride, ryanex, sodium fluosilicate, and a chlorinated camphene should result in a cheaper and more effective material against all insects damaging this crop. Since benezene hexachloride and the chlorinated camphene proved quite effective against the yellow surgarcane aphid as well as the borer, it is significant that they are also toxic to the rootstock weevil. Of course an insecticidal mixture that killed all the important sugarcane pests would be ideal; indeed, judging from the results obtained with these newer insecticides, this goal now appears to be a definite possibility.

DDT CONTROLS GRAPE INSECTS

The grape leafhopper has for years been recognized as one of the more serious insect pests of Concord grapes in the important Great Lakes region. Serious injury to the leaves, which manufacture organic substances in the presence of light, resulted in material losses

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of those sugars going to make up quality in the mature fruit. Verifying this conclusion by enclosing vines in cages along with grape leafhoppers, Pennsylvania station workers found that grapes produced in the presence of a high population were definitely lower in sugars.

Among the materials tested for grape leafhopper control, DDT proved outstanding. On the basis of several years' trials one application was found sufficient; in fact so complete was the control that the leafhopper is no longer a major problem. Other grape insects yielded to DDT, notably the grapeberry moth, which has long been a troublesome pest; light infestations can be controlled by two applications, but heavy infestations may require four. The rose chafer also succumbed to treatments with DDT.

As a result of these studies, 95 percent of the grape growers in Erie County, Pa., used DDT in 1946 to replace lead arsenate and nicotine sulfate. Chemical analyses revealed no DDT in the expressed juice. Since a large portion of the Concord grape crop of Erie County is processed for juice, this finding is a highly important one to the consuming public. Two technical papers and two articles in a food packing journal have appeared as a result of the investigation.

PARASITES AID CITRUS SCALE CONTROL

Scale insects are a serious menace to the great citrus industry of California. Rough estimates indicate that as much as $5,000,000 is spent annually by California growers in efforts to control citrus pests—principally scale insects. Continued use of great quantities of insecticides not only means large outlays of money, but the indications are that certain of the materials may have accumulative harmful effects on the trees themselves. As a result, there has been an increasing interest in the natural control of scale insects by beneficial insects.

The California station has played a vital role in the introduction and study of these beneficial insects. A complete review of the station's activities in insect control by parasites is quite impossible in this limited account, but certain accomplishments illustrating the extent and value of the recent work are presented.

The yellow scale of citrus has been controlled in several districts of California by the introduction of a new parasite, *Camperiella bifasciata*. The long-tailed mealy bug has been partially controlled in Orange County by parasites introduced from Australia, South America, and South Africa. The black scale has been controlled in most of the citrus areas of the State by another new parasite, *Metaphycus helvolus*, brought in from South Africa. The introduction and establishment of this insect is probably worth $2,000,000 annually to the citrus growers of southern California.

A very pertinent sidelight on these investigations is the fact that introduction of new and potent insecticides such as DDT into the citrus protection campaign has not proved an unmixed blessing. For instance, the important Vedalia beetle that normally controls the cottony cushion scale in central California is killed by DDT. Leaves with a complete coating of DDT retained sufficient of the chemical for 2 months to cause complete kill of these beetles. Station researches revealed, however, that when the DDT treatments were not continued past July 1 the Vedalia beetle reentered the sprayed groves in sufficient numbers to control the pest. Because of its persistent effect, spraying with DDT after July 1 was thus definitely out of order.

These investigations are leading to the development of effective programs of scale insect control that can take advantage of natural parasites and at the same time make use of new and effective insecticides such as DDT.

RESEARCH AIDS UTAH TOMATO GROWERS

Compared with Indiana and New Jersey and other large tomato-producing States the Utah tomato crop is relatively small. It is, however, an important industry, as some 2,500 growers produce tomatoes for local consumption and processing in the State's 25 canneries. Utah weather is ideal for producing high quality tomatoes; it is also favorable to insects. Among the pests present, the tomato fruitworm—known as the corn earworm when attacking corn—is a menacing enemy. Damage from this insect is highly variable, ranging from almost none in some years to 30 percent of the crop in others. A severe outbreak may cause up to $300,000 damage in a single year. Faced with the possibility of serious losses, Utah growers adopted the pratcice of spraying, at an estimated annual cost of $40,000 or more for insecticides alone. When only a few fruitworms developed, however, this expenditure was practically a total loss.

The Utah station, called upon to assist in the problem, made a careful study of the habits of the tomato fruitworm, in cooperation with the Department. The eggs, deposited on early sweet corn and tomatoes, were found to hatch in a few days and the worms to attain maturity in about 2 weeks. Records by the station workers revealed a close relationship between the number of eggs on the tomato plants during fruit-setting (July 15 to August 15) and the infestation that followed. One egg per 100 leaves resulted in infestation of 3.5 to 4.5 percent. Fewer eggs than this gave such light infestations that dusting proved impractical and an economic loss. This simple but effective procedure for determining the potential damage to the tomato crop has saved the growers of Utah many thousands of dollars.

Incidental to the fruitworm survey this station, cooperating with one of the processing plants, has developed more effective power equipment for applying insecticidal treatments.

In years of moderate infestations one thorough and properly timed application of insecticide proved just as effective as two or three such treatments. Further research will determine the best methods for combating the severer outbreaks.

DDT CONTROLS POTATO FLEA BEETLES

The potato tuber flea beetle is one of the most serious flea beetles attacking the potato crop in Oregon. The adults eat the foliage and the young injure the tubers. In many plantings the loss amounts to 25 percent or more of the first grade potatoes and in some cases it may rise to almost 100 percent. Studies by the Oregon station began with a careful analysis of life history and feeding habits of the pest. Two species were found to be involved and both are harmful.

Various materials were tested as control measures. Among them, repeated applications of a 3-percent DDT dust, when properly timed and thoroughly applied, proved very effective. No longer is the potato tuber flea beetle a practically uncontrollable pest in Oregon. As a result of this work large numbers of Oregon potato growers have

adopted DDT dusting as a regular practice. Elimination of the 25- to 100-percent flea beetle damage to potatoes makes a substantial saving to the producers.

MILKY DISEASE FOR JAPANESE BEETLE CONTROL

Promising results have been obtained by the Delaware station, cooperating with the Department in the control of Japanese beetles by inoculating grub-infested soil with spores of the milky-disease fungus. All areas in the State favorable to the increase of the beetle were inoculated at the rate of two ½-acre plots per square mile on moderately infested soils and four ½-acre plots per square mile on severely infested soils. Inoculations in urban areas were even greater. The workers believed these inoculations adequate to insure the ultimate spread of milky disease over all potential Japanese beetle breeding areas in Delaware.

Checks were made over the 5-year period, 1942 to 1946, on the percentage of infected grubs. Changes from year to year were not found large, but a definite upward trend in the percentages of infected grubs was recorded; these were 2, 8, 17, 27, and 31 percent, respectively, for the 5 years of the survey.

The effectiveness of the State-wide distribution of milky-disease spores as a means of controlling the Japanese beetle was thus well demonstrated. Approximately one-third of the grubs occurring in Delaware soils are now infected with milky disease. The concurrent decrease in adult beetles and in injury to trees and other plants has been widely noticed and appreciated by the general public.

RED SPIDER CONTROL IN GREENHOUSES

Red spider control is one of the most difficult problems confronting Ohio growers of greenhouse vegetables. The tomato crop is extremely susceptible to damage by this pest, particularly where two crops are grown annually, as is the common practice in certain Ohio greenhouses. Uncontrolled, the red spider is capable of reducing the value of the greenhouse tomato crop of this State by as much as $10,000 per acre in a year. Investigations by the Ohio station on such injury to tomatoes in 26 different commercial greenhouses revealed two interesting facts: Damage was greatest where two crops of tomatoes were grown annually, but was not serious where tomatoes were alternated with lettuce.

Investigations of materials that might aid in controlling this pest showed azobenzene to be particularly promising. The cost of materials and labor for fumigating an acre of greenhouse area with azobenzene was approximately $17; the cost of spraying with the same material was $23.50. Four fumigations or eight sprayings with this material were required each year. Thus on an annual basis fumigation proved much less costly than spraying. Besides controlling red spider azobenzene had the further advantage of effectiveness against the tomato rust mite as well. Among the other materials tested, hexaethyltetraphosphate controlled red spider effectively but injured the tomato plants. Moreover, a new proprietary material containing DDT and a red spider killing ingredient gave promise as a general purpose greenhouse spray.

A noteworthy sidelight to these investigations was the indication that repeated spray applications on isolated infestations resulted in

the selecting out of red spider strains that appeared partially immune to certain materials. This development suggests the need for discovering completely effective killing agents. In spite of this possible drawback, the studies have shown the value of azobenzene for red spider control and have contributed to the successful production of greenhouse tomatoes, a valuable and important greenhouse crop not only in Ohio but in other States as well.

CARROT YIELDS INCREASED BY DDT

Carrots are one of or important truck crops, being used extensively as a vegetable and as an ingredient of canned soup and other food products. In Wisconsin, carrots are attacked by a virus disease known as yellows, which tends to stunt the plants thereby reducing both marketability and total yields. Estimates in commercial fields of southeastern Wisconsin revealed infections as high as 75 percent, with a range of 15 to 60 percent not at all uncommon. Yellows-infected carrots also offer a serious harvesting problem, since the small stunted plants are largely missed by mechanical harvesters.

The problem was attacked by the Wisconsin station at the request of the growers. Rather unexpectedly a practical solution was found in spraying with DDT which, although primarily an insect-killing agent, proved successful indirectly in checking a plant disease. In other words, DDT killed the 6-spotted leafhopper which spreads the yellow virus from plant to plant. Since yellows attacks many different kinds of vegetables and flowers, these findings have wide significance beyond carrot production and are important in many States besides Wisconsin.

Results proved best where carrots were sprayed early in the season, beginning about June 24 when the plants are 4 to 6 inches high. Three June and July sprayings reduced the proportion of yellows-infected plants by 32 percent and increased the yields by 50 percent, or from about 11 tons to nearly 17 tons per acre.

The successful sprays were made up with 2 pounds of DDT in 100 gallons of water applied at the rate of 100 gallons per acre. There is no doubt that treating carrots with DDT is a paying proposition in a field where the yellows disease is a problem. The cost of the insecticide for three applications was $6 an acre. Conservatively assuming a 40-percent yield increase instead of the 50-percent maximum, the profit thus proved to be $85 an acre; where roots under 1½ inches in diameter were discarded, as in cannery grading, the profit from spraying reached $95 an acre.

SIXTY SHEEP PER MINUTE TREATED FOR TICKS

A new spraying apparatus developed by the Idaho station is proving of great value to Idaho sheep producers in their battle against sheep ticks. The treatment of 1,500,000 sheep ranging over a vast area of mountainous country presents a tremendous problem. The cost is also an important factor, since the value of a single sheep in normal times does not warrant large outlays for protection. Sheep ticks are insidious enemies, causing a steady drain on vitality. Consequently, as a result of infestation the ewes are often unable to produce a normal crop of lambs. DDT sprays will control these ticks but are difficult to apply under range conditions.

The new machine developed by the Idaho station has an ingenious arrangement of nozzles that completely covers the animals with spray as they pass through a chute. Pressured by a power sprayer, the liquid suspension of DDT penetrates deeply into the wool. The operation is fast and utilizes materials so efficiently that sheep can be treated with DDT at a cost of 2 or 3 cents per animal for materials and at the rate of 60 sheep per minute. For example, a band of 8,600 at Challis, Idaho, was sprayed between 9:30 in the morning and 4:00 in the afternoon. In this way some 50,000 sheep have thus far been treated for ticks as a result of the development of this cheap and rapid method of application.

Five months after treatment the DDT on the wool was still killing the ticks. In the meantime the wool had grown considerably, leaving the DDT residue on the older parts of the fleece. When warm spring days lured the few remaining ticks to the outer surface, they contacted the insecticide and soon died. As a result the wool in spring was finer, softer, longer, and of better quality on the animals so treated.

This rapid and efficient way of treating large bands of sheep should greatly reduce the losses, both in weight of the animals and in wool from rubbing. This would be true not only in Idaho but in other sheep-raising areas of the country as well. In addition to these gains, reduction of sheep ticks to negligible numbers will reduce blowfly strikes on tick-infested animals and deaths from anaphylactic shock that may follow the sheep tick bites. In brief, the benefits of the treatment were healthier sheep and lambs and improved grades of wool that brought top prices on the Seattle market.

PICKING CONTROLS COWPEA CURCULIO

During World War II, serious curculio damage to cowpeas was frequently reported from Virginia, where the crop is mainly grown as a vegetable for fresh consumption. In fact, the cowpea in many areas of this State and other parts of the South is a mainstay in the food supply of farm families. A total loss of the crop, such as occurred in some instances, was calamitous; partial loss from injury to the pods was, to say the least, serious.

Varietal plantings, established by the Virginia station in a search for resistant kinds, revealed that black-eyed peas, the best food variety, are more susceptible to curculio injury than are the less desirable kinds. Injury was reduced by frequent and complete harvesting of all mature pods. Harvesting at weekly intervals was particularly effective in farm gardens where plantings were sufficiently isolated to remove or reduce the hazard of outside reinfestation. Studies on the life history of the cowpea curculio in Virginia disclosed a single generation only and a high winter mortality. In one experiment, winter survival was only 2 percent. The curculio was found not to migrate over great distances.

Weekly harvesting of all mature pods is a relatively simple practice which, in view of these results, should enable the farm housewife to have ample supplies without resorting to costly insecticides. The findings are important to a large group of rural people both in Virginia and in other States where the cowpea is a mainstay vegetable crop.

ONION THRIPS YIELD TO NEW INSECTICIDES

Recent findings by the Texas station promise a successful ending to the long fight against onion thrips in the important onion-producing area known as the Winter Garden district. Here is located a potential million dollar onion-growing industry, one of the greatest handicaps to which has been the onion thrips. Year after year this tiny but numerous insect has exacted a heavy financial toll on the growers, sometimes causing a complete loss of crop. Estimates showed an average annual loss of 25 percent which, in terms of money, meant $250,000 or more, depending on the price. Even more disturbing than the heavy losses was their great variation from year to year. Because of this situation, the growers could never estimate the size of their crops in advance. This unreliability of yields disturbed the harvesting and marketing plans and tended toward an unstable industry and uncertain returns.

For years many different materials and methods of treatment were tested by the station workers located in the Winter Garden area. Finally, in 1944, the new insecticide DDT was included in the trials and for the first time a successful control of onion thrips was in sight. DDT proved both economical and effective and potentially capable of eliminating a major part of the $250,000 yearly loss. More important yet, its use gave promise of a stable production. Yields on experimental fields were increased from a previous average of 226 bushels per acre to 284 bushels where the crop was treated. Coincidentally the number of thrips was reduced to about one-third that on areas where DDT had not been used.

In subsequent trials, 5 percent DDT in a dust mixture containing 87-percent sulfur proved even more effective against thrips than did a 5-percent DDT dust alone or with 25 percent sulfur added. Correlated timing experiments indicated the desirability of applying DDT dusts before the thrips became well established in the leaf bases where they were protected from the insecticide.

Although additional research is needed on timing of the applications and on other features of the treatment, DDT has been so successful that the growers are quickly adopting its use. In 1946, with only a portion of the acreage in the Winter Garden district under DDT treatment, thrips losses were estimated to have been reduced by at least $50,000. There is every assurance that when the value of DDT becomes more widely recognized, this figure will be very materially increased.

BARK BEETLE HABITS AID CONTROL

A severe outbreak of the pine bark beetle in eastern Virginia during 1936 gave rise to an intensive study by the Virginia station on the life habits and control of this destructive pest. The beetle is not a new insect, having been found responsible over the years for widespread injury to the spruce and pine forests of West Virginia. The species has a peculiar history—large infestations occur with much ensuing damage and then for a period of years only a few individuals are to be found.

Research workers of the Virginia station found that the pine bark beetle and several other related species attacking pines are most often observed in mature trees. This habit of concentrating on mature trees

pointed the way to the reduction of losses by employing logging practices that would remove mature trees before they reached the stage of susceptibility. Furthermore, these workers observed that pulpwood brought into the storage yards and allowed to lie there for a long period became heavily infested with bark beetles. Injury to the pulpwood logs was severe, but even more serious was the spread to nearby trees that were approaching maturity. A destructive cycle was thus set up whenever pulpwood was allowed to remain too long in the storage yard. In such cases the beetles returned from infested trees and severely injured new pulpwood brought into the yards.

These findings have been given to the paper companies for their use in reducing storage losses in pulpwood. This can readily be done by management of the loading and unloading operations so that pulpwood is moved more rapidly, thus effecting a large saving; in fact, this saving alone should more than offset the cost of this series of studies for a good many years to come.

AIDS TO HONEY PRODUCTION

Research at the State experiment stations is aiding greatly in the development of successful beekeeping. Among the current accomplishments of such productive studies are those dealing with "short haul" migratory beekeeping in Maryland, selection of food plants producing nectars of high sugar content in Iowa, development of disease-resistant strains of bees in Iowa, and determination of agricultural chemicals that cause bee poisoning in Washington. An example of recent work by the Pennsylvania station is reported upon more fully below.

PROTECTING BEES FROM WINTER LOSSES

Severe winter losses of bees present an important problem to beekeepers in Pennsylvania and many other northern States. Records show that over a million colonies of bees are kept on farms and in suburban areas of northern and central Pennsylvania and that only a small proportion of them, mostly in the larger apiaries, are provided with winter protection. Investigation by the Pennsylvania station on the nature and prevention of winter losses led to important findings. Hive humidity apparently had a marked influence on the overwintering of bee colonies and the condition of the pollen and combs. Heat, carbon dioxide, and water are produced when bees consume honey. The air within the hive thus comes to contain much more water than does the outside air. This builds up excess water in the hive which, if not removed, causes molding of the comb and pollen and dilution of the honey and nectar.

Studies were made of the effect of various methods of winter protection upon hive humidity. Hives placed in a large box with 5 inches of straw or hay in the intervening space and with a ventilating space between the top of the hive and the lid of the packing case gave excellent results; the combs and honey were as dry, clean, and wholesome in the protected hive in spring as in the preceding fall. Furthermore, bees in the packed hives consumed 6 to 8 pounds less honey in the overwintering period than did the unpacked colonies.

The results indicate that if all bees in the area were properly protected, winter losses would be greatly reduced and large quantities

of honey saved; in fact, the annual savings were estimated at 7 million pounds with a retail value of more than $2,000,000. Important savings in honeycomb also accrue to beekeepers following the new practice.

ACHIEVEMENTS IN ANIMAL HUSBANDRY

The largest individual segment of American agriculture lies in the broad field of animal production. During each year since the recent war, the cash income to farmers from livestock and its products has been well over 12 billion dollars and has constituted considerably over half the total farm-marketing receipts. This attainment has to a large degree been possible because the State experiment stations and the Department have made every effort to meet the ever-changing problems of the industry.

These problems in animal production are in reality established by the consuming public, with its continuing demands upon the industry for more animal products in the national diet. This presents an impelling challenge to the research worker and producer alike to find under existing resources new and more efficient ways of meeting the situation.

The statement that research is never static is thus especially true for animal science. For example, the chemist and the animal husbandman yesterday determined the productive value of different sets of rations with a given kind of livestock and thought the task was finished. But today, because of the efforts of animal and plant breeders to improve them, the livestock farmer has a new kind of corn, and a new kind of hog, cow, or hen to feed it to. How do these "new" crops and animals respond? Old answers do not apply, so new approaches are needed.

But even without changes in crops or animals, new problems are continually posed. These new studies are varied in nature and diverse in origin; they have arisen principally, however, because of the application of technological advances over the whole field of agricultural science. The needs may well be expressed: "The greatest amount of the best quality product at the lowest possible cost."

As indicative of progress in animal industry and of milestones that have been established through farmer acceptance, the following examples of current research accomplishment are presented.

BEEF CATTLE

Beef production in the United States has been above 10.7 million pounds since 1943, a figure not equaled by recorded data from any other country; this represents an increase of almost 100 percent from the 5.8 million pounds produced in 1929. Per capita consumption likewise has gone up from 49.7 pounds to a high of 61.2 in 1942. These increases have occurred despite the fact that, compared with other forms of animal husbandry, beef production is less intensive even in its narrowest aspects.

The need for more space can be traced from the early days as population expanded westward. With the free movement of cattle on an open range of vast extent, animals remained so short a time on any given spot that no problems were apparent. Neither was there economic need to increase the production per acre because there were so many acres. With the growth of fencing, and the resulting restric-

tions on available grazing areas, many problems began to appear. Only recently have we begun to realize the need for conserving our most valuable national resource, the soil, with a forage cover that would lend itself to beef production, even in the older areas. Thus, on range and farm, research has kept abreast of the needs by helping farmers to provide more food.

FERTILE SOILS PRODUCE MORE AND BETTER BEEF

Common observation has revealed that some soils produce a more luxuriant growth of forage than others, and even our own American Indians had terms for lands that caused illness in livestock. As early as 1904 Texas veterinarians reported a condition in cattle known as the "creeps.' A similar trouble appeared in Montana about the same time. No explanation of the cause could then be given, but these cases were probably associated with the fact that the better lands were placed under crops and grazing was left to the "poorer" soils.

By 1919 reports of a similar trouble came from Alabama and other States. Because their relationship to the soil was at first not recognized, these problems of the beef cattle industry remained unsolved until a report from South Africa described a similar condition in cattle and attributed it to a deficiency of phosphorus in the soil. The lack of this element not only resulted in bone weakness and depraved appetites such as bone chewing, but also in diminished growth, with greatly reduced calf crops and decreased milk production as associated effects.

On the basis of these findings, workers at numerous experiment stations in the United States now began to study plant and soil conditions in relation to animal nutrition. These investigations can best be illustrated by reporting studies just concluded at the Texas station in cooperation with the Department. Here, in extensive experiments extending over several years, the demonstration of a phosphorus deficiency in the soil has now led to improved pasture fertilization. This has greatly increased the yield and nutritive value of the forage, which in turn has raised the quantity of animal products obtained. Typical of these results over a 2-year period in one area a section of unfertilized soil produced 33,135 pounds total calf weight, as compared with 37,850 pounds on a similar untreated area where bonemeal was fed and 60,192 pounds where the soil was fertilized with 200 pounds triple superphosphate 45 percent P_2O_5 per acre. Further advantages of supplying the phosphorus in this deficient area are reflected in a high percentage calf crop, a marked shortening in the calving interval, and increased weight and better condition of the breeding cows. According to the Texas station, widespread acceptance of the fertilizing practice is indicated by the progressive doubling of the amount of superphosphate use on pastures in the State during each of the last 3 years.

TOXIC SOIL ELEMENTS MAY DECREASE MEAT SUPPLY

In contrast to the hunger of soils for some minerals is the harmful excess of certain elements in others. The story of the harmful effect, as manifested in toxic grains, hays, etc., of excess selenium as found in the Pierre shale outcrop soils of South Dakota and neighboring States, is well known. In the early days the causes of such troubles were unrecognized and so were treated as ordinary diseases. Now,

however, our researchers have learned that to get at causes the combined talents in many fields of science must be brought to bear on the problems at hand.

It is not surprising, therefore, that when a strange new malady was observed in Kern County, Calif., the solution required much less time than for the phosphorus deficiency problem cited above. Many ranchers in this area reported severe abnormalities in their cattle, including loss of weight, change in color of hair coat, and extreme unthriftiness. Suckling calves were the most severely affected.

In their study of this problem, it was not long before the station veterinarians eliminated the possibility of any ordinary cause. Meanwhile, cognizant of many facts already known, scientists in other fields were also working on the problem and fitting the parts together into a more complete picture. The search was not confined to Kern County, but included the mountains forming part of the watershed of the affected area. There the rocks were found to be high in molybdenum; analyses of soils and plants on which affected animals were grazing indicated a similarly high content. Thus was the cause finally tracked down. It still remained, however, for the chemist to reveal how to remove the harmful effects of this element, so toxic in excess.

Eventually the station was able to conclude not only that an excess of molybdenum in the soil causes the trouble, but that it can be remedied by feeding the cattle small amounts of copper. Marked improvement followed the introduction of this practice, and so permitted the area to enter into beef production on an economically profitable scale.

Problems like those considered above are baffling. For instance, the results of further studies on feeding copper at the Colorado station have been put into practice on certain ranches where they have already prevented $30,000 worth of range bulls from becoming worthless cripples from a rachitic-like condition. Although the immediate question has been answered, a full solution of these problems cannot be attained until the causes are studied further and the exact physiological relationships of the copper therapy are investigated.

Problems such as these are constantly recurring in these and other States on account of the widely varied soil types, kinds of plant cover, and the availability of soil nutrients.

In studies such as those considered above, the use of radioactive isotopes of many of the essential elements, recently made available for experimental work, provide a promising means of answering some of the basic questions involved.

BEEF CATTLE A GROWING ASSET TO THE SOUTH

It is not generally realized that cattle production in the United States really began in Florida some 400 years ago, nor that the number of head in the South Atlantic and South Central States has increased by over 2 million in the last 10 years until now they contain approximately 25 million cattle or nearly one-third of the total for the whole United States. The greater economy in cash crops and the opening of the western range naturally prevented full development of this industry in the South. There now exists a realization that the Southern States present tremendous opportunities in livestock production, because they permit year-round grazing and are near the great consum-

ing centers. Although the increased utilization of soil-saving crops has provided an abundance of forage material, not all the problems are solved, nor do old answers obtained in other regions always apply.

In the area of the Coastal Plain that is devoted to timber production very extensively, cattle have been frowned upon because their presence was believed harmful to new growth of the trees. Forest fires always have also been a constant hazard. Although soils may vary from section to section, thus creating many new problems for the farmer, certain studies by the North Carolina station and the Department well illustrate how the whole region could become far more productive than it has been in the past.

This work indicates that cattle can be grazed in either logged or unlogged areas without harm to the pine seedlings. As a result of this work increasing quantities of North Carolina beef are now being produced on the 9,000,000 acres of such timberland. Owners who have adopted the recommended practices are obtaining 25 to 50 pounds of beef per acre each season while they wait for the trees to grow up to cutting size; at the same time the hazards from forest fires are greatly reduced.

Each State still has its characteristic problems, the sandy soils of Florida for instance, being highly deficient in certain essential minerals; and in all sections the need exists for developing kinds of livestock that will be most productive under local conditions.

GOOD MANAGEMENT INCREASES PROFITS TO THE CATTLEMAN

The country is now faced with a shortage of beef because of the high previous movement of animals to the feed lot and slaughter. What then can be done to increase the supply? Economic studies of the western ranch operations over many years have revealed two startling facts. One is that in many herds the calf crop may go as low as 55 percent; the other is that the weight of the weaned calf is frequently as low as 350 pounds. It has also been established that profitable ranches do not drop below an 80 percent calf crop and usually they produce heavier calves at weaning. Thus it becomes evident that if reproductive rates could be raised even to 75 percent, a great potential reservoir of meat would soon become available.

Many factors other than more calves enter into a profitable calf crop. Typical of the efforts being made to meet these problems are results obtained by the Utah station, which has found that good heifer management is most important to increases in efficiency; this has been verified in practice by ranchers cooperating with the station. The investigation has revealed that only 33 percent of range heifers, bred as yearlings, produced live calves as 2-year-olds, and difficult calving was common; when bred at an older age this low reproductive rate was avoided. The value of good range feed for maintenance of health and thrift in growing heifers prior to breeding—thus insuring better calf crops—was most noticeable between those grazing on lands reseeded with crested wheatgrass, which produced a daily gain of 1.73 pounds, and similar heifers grazed on outside areas, which averaged only 0.89 pound of daily gain. Studies such as these are pointing the way to more and efficient production.

SWINE

Swine are valuable and efficient producers of vitamin-rich meat and fat, both sorely needed throughout the world. In the past, most research has been confined to seeking the most efficient rations per 100 pounds of pork produced, with the major portion of the work done in the corn-producing States. Experimentation has already shown the fattening values of feeds other than corn, and studies are still continuing to find cheaper methods of producing pork.

RESEARCH HELPS SAVE NEEDED GRAIN

With the great need for saving feed, recent studies by the Wisconsin station are indeed important. Identical rations were fed to different lots of hogs except that one lot received no salt. Since the pigs receiving salt at the rate of 0.5 percent made an increase average daily gain of 0.2 pound, about $20 worth of feed was saved for each dollar of salt used; in other words, each pound of salt saved 9.4 pounds of feed.

Workers at the Alabama station have reported that the calories produced from an acre of dried sweetpotatoes in the South are greater than from an acre of corn in the Corn Belt, but past feeding trials comparing corn with sweetpotatoes have not favored the latter. The station has now found that the deficiency in dried sweetpotatoes is not, as previously supposed, in their vitamin B content, but is in their deficiency of protein or more specifically of amino acid.

When properly supplemented with fish meal, hogs made satisfactory gains on sweetpotatoes, requiring 96 pounds of fish meal and 385 pounds of dried sweetpotato per 100 pounds of gain. Tankage or meat scrap were significantly less effective than fish meal as a protein supplement to the dried sweetpotatoes. Dehydrated unmarketable sweetpotatoes in producing areas are estimated as equivalent to several million bushels of corn; this provides a valuable substitute feed whose use in hog fattening is now on the increase.

BABY-PIG LOSSES DECREASE PORK PRODUCTION

One of the most serious present-day problems confronting hog producers is the high mortality of baby pigs. Its gravity is emphasized by the fact that plans are being developed to investigate these losses in a widespread coordinated attack made possible under the new Research and Marketing Act. The extent to which faulty nutrition influences the death rate has not yet been established, but the work of certain experiment stations as reported in previous years indicates that nutrition must not be ignored.

The most recent findings, reported by the Washington station, indicate that deaths of baby pigs can be greatly reduced. These studies have shown that these high losses are definitely associated with vitamin deficiencies in the ration of the sow and that the lack of any one of three vitamins, namely riboflavin, thiamine, and choline, results in unsatisfactory litters.

Riboflavin deficiencies caused erratic appetites in sows, early parturition, and litters of hairless pigs born dead or dying soon after birth. Besides premature births and complete mortality, the lack of thiamine produced weak-legged pigs. Furthermore, surviving pigs

farrowed by sows fed a vitamin-deficient ration required more feed to make a pound of gain. Sows on a choline-deficient ration farrowed on schedule, but produced weak pigs with leg abnormalities, muscular incoordination, and heavy mortality in the litters. These findings by no means completely solve the problems and it remains for the above-mentioned concerted approach to provide a complete picture of the situation.

SHEEP AND WOOL

Although the number of sheep in the United States has declined markedly in recent years, the industry still represents a sizeable segment of our animal economy. Moving from its early center in Vermont, thence to Ohio and other Midwestern States, the industry is now largely concentrated in the western range area.

In previous years, breed improvement and lamb feeding studies have been reported and the findings have been put to use by producers with marked success. However, perfection has not been attained either in the West or in the East where problems are markedly different and where a revived interest in sheep raising is taking place.

SOUTHERN SHEEP IMPROVED BY CROSSING WITH NEW WESTERN BREED

Although one seldom thinks of the South as a sheep-producing area, the fact remains that half of the lamb consumed in the United States is consumed east of the Mississippi River. Thus efforts to increase sheep production in this region are in line with reducing costs and the venture fits in well with the economy practiced. The work of the Florida station and the Department as to the value of the new Colombia breed developed at the Department's cooperative Sheep Breeding Laboratory at Dubois, Idaho, is therefore pertinent.

In these studies it was found that the Colombia sheep fail to reproduce as efficiently in the northern Florida environment as under conditions at Dubois, where they were developed. However, ewes produced by mating Colombia rams to native Florida ewes reproduced at a level superior to either parent strain and their fleeces were considerably heavier than those of the native stock. The lambs from this cross were also greater in number and heavier at weaning. Hence, the use of Colombia rams on native ewes has proved to be an effective means of increasing production of both wool and lamb in the South. The use of western ewes for flock replacements is now on the increase throughout the whole southern region. As new types of sheep are developed, however, new problems will also inevitably appear because of such factors as differences in soil, climate, and feed.

SHEEP PROFITS INCREASED BY IMPROVED BREEDING METHODS

Considerable progress has already been effected through the use of new or improved breeds of sheep on the western ranges.

The New Mexico Wool Growers' Association has stated that the program of wool improvement through selection of breeding animals for greater wool length has increased the income from sheep in New Mexico about 1½ million dollars. This practice, resulting from studies by the New Mexico station, is now made the basis for selecting rams at the annual State sale. Both producers and station workers believe that further improvement is possible through present investiga-

tions of how to select among breeding rams at various stages of wool growth; other characters such as face covering, skin folds, and lamb production are problems that also are being investigated.

The Wyoming and Utah stations have also made their contributions to increased efficiency in wool production through studies demonstrating great differences in clean fleece weights within individual flocks. By culling and establishing a breeding program around selected animals, the average fleece can be increased by 2 to 5 pounds, thus permitting an average gain at current wool prices of around $3 per sheep. This practice is being adopted with marked progress in improving the flocks of over 60 sheepmen.

DAIRY CATTLE

An international industry has been built on the dairy cow and to her in one form or another a large segment of this country's population owes its livelihood. The problems that have received attention resulted from the increase in number of cows and also from the lack of information on how best to feed the animals to get more milk and how to handle the product for maximum use. For those selected cows listed in herd improvement associations, the records show an increase of some 200 pounds of butterfat per cow annually in a 40-year period, but the average cow of the country today produces only 20 pounds more of fat per year than did her average ancestor of 1907. This situation exists in spite of the great volume of profitable research that has been done. It constitutes a challenge to the dairy research worker of the present and the future.

GOOD FEED IMPORTANT FOR BULLS

Practically all good dairymen will admit that the bull is half the herd, but frequently his nutrition is ignored and he gets the "leftovers." Increased milk production in dairy cattle breeding programs depends largely upon proven sires. Moreover, their use is now greatly increased through artificial breeding and the maintenance of special bull centers. The rapid growth of this method of breeding has focused attention on the need for prolonging the usefulness of well proven bulls and has at the same time revealed a lack of knowledge on their nutrition. For instance, the vitamin A needs of cows and calves have had much study, but those of males are still in question; the answers are just now being obtained.

Illustrative of the individual approach that lends itself to completing the picture, the following recent findings of several stations are pertinent. The Indiana station reports that bulls may appear to grow normally and fail to exhibit any easily recognized symptom of vitamin A deficiency; yet it was found that a lack of this vitamin in the young animal results in delayed sexual maturity and in impaired fertility of the adult bull. Vitamin therapy in later life does not improve damage to the reproductive tract caused by a deficiency of vitamin A before sexual maturity.

Confining their studies to the first year of life, workers at the Pennsylvania station have made careful examinations to determine what happens to the testicular tissue in such cases. These examinations were also correlated with the vitamin A and carotene content of the blood. Results showed that the season of year has a marked influence, the

amount of this vitamin in the blood being substantially reduced during the severe winter months. Investigations of the testicle showed that its health depends upon the amount of carotene or vitamin A in the ration. Degenerative changes in the germinal epitheleal cells believed to inhibit normal sperm production were found to vary directly with the vitamin intake, being most conspicuous when low levels are fed.

Further studies on nutrition of calves have been made by the Maryland station, which has established the actual amounts of carotene (provitamin A) needed during calfhood for three breeds over the winter and summer months; at the same time the value of farm-grown materials in supplying these needs was pointed out. These results have shown that during the winter months, Holstein and Ayrshire calves require 30 micrograms of carotene per pound of bodyweight each day between the ages of 4 and 14 months; similarly, Guernsey calves require 34 micrograms. During the summer months, Holstein and Ayrshire calves require about 20 micrograms per pound of animal per day. According to these figures, average U. S. No. 2 grade hay should furnish enough carotene to meet the vitamin A requirements; it is questionable, however, whether the U. S. No. 3 grade would supply it in sufficient amount for an extended feeding period.

These findings emphasize the importance of feeding good quality hay to growing cattle, especially during the winter season; they further emphasize the importance of studies which will lead to the production of good quality hay for dairy cattle and particularly for herd sires.

WINTER PASTURES SAVE GRAIN

Livestock husbandry increases soil fertility, adds to farm income, and improves human nutrition. Particularly is this true in the Southern States, an area lying wholly in that 10 percent of the world's land mass that has been designated as most desirable for the human race. Although even yet the South is on an importing basis from the standpoint of total milk consumption and potential needs, the long growing season and mild winters offer tremendous opportunities once the area problems are solved.

Cows in the Northern States must be wintered on preserved feeds, such as hay and silage; on the other hand, the mild climate of the Gulf Coast and Southeastern States enable the use of grazing during this period with resulting economy in what it costs to produce milk of high nutritive value.

Substitution of fertilized winter pastures of ryegrass and crimson clover for corn silage in the ration of dairy cows at the South Carolina station saved stored feed and produced more and better milk. Over a 98-day period when two groups of cows were fed the same amount of concentrate those on pasture produced an average of 275 pounds more of 4 percent fat-corrected milk per cow, ate 2.5 percent less hay, and made 95 pounds more gain in live weight than did the barn-fed cows. The pasture used by each animal was equivalent to a saving of over 1.5 tons of corn silage which could then serve as feed during the summer season of poorer forage.

In addition to this the milk produced at the beginning of the experiment contained a vitamin A activity equivalent to 401 micrograms

per quart. The vitamin A potency of milk produced by the barn-fed group decreased to 295 micrograms (26 percent) per quart, while that of the grazing animals increased to 656 micrograms (64 percent) per quart. Thus the pastured group yielded an increased quantity of a product at the same time materially improved in nutritive value, and without the need of silage.

Similar studies by the Georgia station have demonstrated the value of small grains for winter grazing. In these tests, fertilized winter oats increased the production of milk by almost half a gallon per cow per day, reduced feeding costs by one-third, and in the latest test gave a net profit of $135 per acre over all costs of pasture and feed. As a result of these experiments, the acreage of winter grazing in Georgia has tripled the total now exceeding 200,000 acres.

In the South, extra summer grazing crops are helpful. Eight years' work with various crop combinations at the Virginia station has shown that Abruzzi rye, ryegrass, and crimson clover hold up well for late fall and early spring grazing. Sudan grass was sown for summer forage. Alfalfa also proved excellent for midsummer pasture.

DIFFERENT TYPE OF COW NEEDED IN THE SOUTH

One factor that has prevented the rapid advance of dairying in the warmer sections of the United States has been the inability of our breeds of dairy cattle to withstand the summer heat. In an effort to determine what to do about it some of the States concerned have been attacking the problem from various angles. For example, the North Carolina station has found that high humidities and temperatures have a definite depressing effect on milk production by present breeds of cows.

A partial answer to this reduced milk production at higher temperatures has been given by workers at the California station, where summer heat is also an important problem. Under carefully controlled conditions it was determined that the upper limit of heat regulation for lactating Holstein cows is about 80° F. When temperatures are maintained above this point for more than 24 hours, the animals tend to become overheated; at the same time there is a reduction in feed and water intake, followed by a natural decrease in milk flow.

Since it is known that cows do not sweat, no large quantities of water are needed to replace the body moisture ordinarily released by sweat glands. The drop in milk flow is explained, therefore, by the reduced water intake, a definite relation having long been known to exist between a cow's water requirement and her food consumption and milk production.

If present breeds are to do the job without this reduction in milk flow it will be necessary to consider heat tolerance in the breeding programs. This approach has been followed by the Louisiana station, where studies suggesting that the ability of dairy cows to tolerate warm weather is inherited. This conclusion was reached after a 2-year study had disclosed that differences in ability to tolerate heat exist among groups of daughters by different sires. Measurements of this ability were based on body temperatures of cows recorded on warm days. Furthermore, differences were found between breeds of dairy cows, with Jerseys proving more tolerant than Holsteins; within

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each breed there were also variations attributable to differences in sires.

Estimates as to the degree of heritability ranged from 15 to 30 percent of the character selected for in the basic generation used in the breeding program. If a dairyman would save as breeding stock those females and a bull averaging on warm days 1° F. lower in body temperature than the average for his entire herd, he could expect their offspring to average from 0.15 to 0.3° lower than his herd average. This process, though slow, offers encouragement to the final development of strains of dairy cattle highly tolerant to warm weather.

Individual studies of milk production by cows in the warmer parts of our country have arrived at the point where the States and the Department are taking over, under the Research and Marketing Act, in a cooperative plan to develop an animal suitable to such environments.

DAIRY PRODUCTS

The origin of man's use of dairy products is lost in antiquity, but probably accompanied the development of the human race. As consumption of these valuable food elements has increased, technological changes have also been made. No longer is butter used solely as hairdressing or churned in a goat stomach attached to the saddle. Similarly, milk handling and cheese making have progressed and ice cream and related items as we know them now can really be considered products of modern times. The industry and related fields have grown from a farm-production basis to one that commands 25 cents of the consumer's food dollar and whose stocks and bonds are listed among Wall Street's dealings.

Each change, each expansion, has created processing problems involving the whole field of science. For instance, World War II demonstrated that without adequate refrigeration butter as such soon decomposed in hot climates, but when all the water was removed, and a pure butter oil produced, it remained edible for 3 months or more, even at high temperatures.

ICE CREAM PROBLEM CREATED BY DIVERSION OF MILK SOLIDS TO INDUSTRY

The great variety of complex mixtures designated as ice cream have created problems for the engineer, the physicist, the chemist, and the bacteriologist. In theory, it can be demonstrated how freezing substances act, but in practice it has been found that some of the existing water does not act as water presumably should, because it is bound to the proteins or sugars in the mix. More and more the demand is growing for a greater diversion of milk solids—and casein particularly—to commercial industrial use. This has necessitated studies on the maintenance of ice cream volume in spite of a decreasing supply of milk solids.

In an effort to meet this problem, the Nebraska station has found that adding fresh or frozen whole eggs to the mix in amounts up to 10 percent by weight resulted in improving the body and rate of whipping of the ice cream without producing an egg flavor. At the higher percentage of eggs, however, both fat and serum solids are reduced. Studies on the making of sherbets disclosed that the use of condensed cheddar cheese whey (32.5 percent total solids) in the mix at the rate of 8 to

10 percent by weight produced a satisfactory overrun and an improved body. Condensed whey can be held frozen for 90 to 120 days and still remain satisfactory for use if first heated to a high temperature to redissolve the milk sugar and milk salts. These studies with whey are of great importance, as this valuable vitamin-rich material is under many conditions a waste product.

Each desirable change of formula from one point of view affects at the same time the physical and chemical composition of the mix. These changes have direct relationships to such factors as volume and shrink, type of machinery used, and the legal requirements to be met. Thus further answers must be continually sought.

MILK BYPRODUCTS UTILIZE FORMER WASTES

World Wars I and II and the present hunger have necessitated marked changes in handling potentially valuable food substances. This situation has been brought about by better roads, improvements in transportation and technological methods, and by the demand for additional foodstuffs not only high in nutritive value but also capable of use in industry. Thus only in the last 35 years have marked advances taken place in the drying of milk products; this has made possible a higher nutritional level for the people in that a constant supply is readily available for baking, candy and ice cream making, and other food industries.

The need for milk on the far-flung fronts of World War II resulted in intensified studies on the packaging of dried milk so that it would keep in satisfactory condition. In cooperation with the Quartermaster Corps, the Illinois station studied the factors influencing the keeping quality of milk powder and many of the findings have been put to use by the industry. The Illinois workers found that dried milk of good keeping quality can be produced if the powder has a high ratio of fat to solids-not-fat. With proper concentration and agitation, preheating the fluid milk to 170° F. or over previous to drying resulted in a superior product. For best preservation a minimum amount of oxygen proved necessary; this was accomplished in part by multiple gas packing (nitrogen, carbon dioxide, nitrous oxide), but especially by regassing after 11 days in order to reduce the amount of oxygen present.

The Illinois studies further revealed that fineness of particle size is a factor in keeping quality. The Oregon station went on to place definite measurements on the particles in their relationship to preservation; dried milk with particles 19.29 microns in diameter kept much better in storage than did milk having a particle size of 8.15 microns.

By no means do these studies solve all the problems involved in the drying process. Of particular concern are those presumably chemical and biological changes having to do with the various flavors of the finished product as compared with the fluid milk itself. The Minnesota station determined that in some way these flavors are caused by changes involving lactose (milk sugar) and the milk proteins; the exact mechanism, however, is still unknown. The necessary machinery for doing the job presents a problem, and is under study by the Minnesota station.

WHAT ARE SOME OF THE CAUSES OF OFF-FLAVORS?

"Flavor" is one thing to one person and something else to another. Because the nature of flavor is so intangible, it is most difficult to associate it with any particular chemical or physical entities. Of one thing, however, we become certain: As flavor problems have appeared we have learned what to do to control them and so to provide products acceptable to the consumer.

That some flavors may originate on the farm is evident from studies completed by the Oklahoma and Mississippi stations. In Oklahoma it was found that skunkweed is an important cause of off-flavors; to control it pastures must either be kept clean of the pest or good temporary forage must be substituted. As a further precaution, the Oklahoma workers have devised a nitric acid method that receiving plants may use to detect the skunkweed defect in milk and cream, thus enabling them to reject these contaminated products.

In Mississippi a different pasture plant was involved; bitterweed flavor in one area caused a factory to reject 100,000 pounds of milk a day. The station found that applications of 2, 4–D (a weed killer) to pastures gave effective control of bitterweed. In the absence of such treatment, however, these studies proved it possible to obtain a marketable cheese from bitterweed milk if it is first diluted with 25 percent water and 25 percent good milk. The solution of this problem, even at a most conservative estimate, saved the famers supplying this factory $1,000 per day.

Even sunlight may cause off-flavors. This has been brought out by studies at the Ohio station which, in gaining an understanding of the problem, has attempted to synthesize the "sunlight" flavor; the precursors are now known to originate in the milk serum. This work disclosed that the critical temperature for off-flavor development coincides with that for liberation of sulfhydryl compounds in normal heated milk. These, along with other aldehyde groupings, were found essential to sunlight flavor development in flash-pasteurized milk.

Clear-glass containers were particularly productive of the off-flavor when submitted to certain wave lengths of light. At the same time, up to 70 percent destruction of the vitamin, riboflavin, occurred with only 20 minutes of exposure. When filters were used that eliminated all wave lengths below 740 millimicrons (red end of spectrum) complete protection was obtained. The results of studies such as this are leading to the use of other than clear-glass containers in milk distribution, thus insuring the housewife a more stable and nutritious product.

Flavor is also related to bacterial decomposition of milk and other dairy products. Fortunately many of these troubles can be controlled by sanitation, as demonstrated by the North Dakota station. Seventeen butter factories in that State were having trouble with off-flavors caused by fat and protein decomposition. In spite of the employment of certain bacterial killing agents, the creameries were still using water supplies contaminated by bacteria capable of breaking down the fats and proteins.

Tests of the germ-killing action of the different chemicals in use revealed marked differences in their effectiveness. Of particular

value has been the finding that where certain synthetic detergents are properly used to wash the butter granules, bacterial action is retarded without the production of noticeable flavor defects. The results of this research have been put into practice by the 17 creameries where the problems originated, enabling the profitable production of 10 million pounds of butter that otherwise would have been sold at a loss.

The above research findings illustrate that the problems of flavor in milk and milk products are very complex; they are physical, chemical, and bacterial in nature and are probably concerned with oxidation-reduction processes. Continuing research is attempting to understand more thoroughly the mechanisms involved so that, knowing them, they can be controlled by preventive measures.

POULTRY AND EGGS

Taken as individual units, poultry raising is seldom thought of as big business, but its contribution to the farm income in 1945 gave the astounding figure of over 3 billion dollars for poultry and eggs alone. Having developed to this size, its problems have naturally multiplied in proportion.

These problems revolve around several fields. In feeding or nutrition outstanding contributions have already been made by the States, but as new feeds come on the market and as better types of birds are developed, further investigations become necessary. Outstanding progress had been made in breeding for high egg production. Additional work is needed to combine high production with disease resistance. Although the farm turkey business in 1945 brought an income of 250 million dollars, the annual per capita consumption of this class of meat was only 4.3 pounds. The development of broad breasted and small types of birds has marked considerable progress in adaptation to consumer preferences. Turkey producers, however, are still faced with the problem of increasing both the fertility and number of eggs produced by their flocks.

These and many other problems remain yet to be solved. That the stations have been actively engaged in doing the job is indicated by the reports that follow.

LIFE OF POULTRY LENGTHENED

Adult mortality is the most important single factor influencing the financial return from flocks. In one year alone death losses of mature birds on the farm reached more than 106,000,000; even at the conservative estimate of $1 per bird, this represents a very high monetary loss to the industry. The causes of such losses are varied and they differ from region to region. For instance, a disease that causes death in one part of the country may be less virulent or meet with higher animal resistance in another. Furthermore, soil and climatic conditions are not without their influence.

As based on observed differences in "livability," efforts have been made to breed fowls possessing a higher expression of this inherent character. Typical of research along this line is the work just concluded at the Massachusetts station, which started out to establish a low-mortality line of Rhode Island Reds by means of selection alone. However, when 5 years of "selecting the fittest" produced inconclusive

results, it was realized that some tool must be used that would increase the complex heritable factors making for increased livability. The method of inbreeding was then resorted to—in this case half brother to sister matings. The process of inbreeding concentrates bad characters as well as good, so it is not surprising that a hidden death-producing character came to light. Fortunately, however, this complication did not upset the program; in several generations a line showing only 14 percent adult mortality was developed, as compared with a high mortality line having up to 59 percent of adult deaths.

Particularly striking are the 10-year studies on genetic control of lymphomatosis in White Leghorns recently concluded at the New York (Cornell) station. This disease has many names, sometimes being called range paralysis, avian leukosis, or big liver disease. Forty percent mortality through the first year of life is the toll taken by it and the Department has estimated that the annual loss exceeds $50,000,000 in value.

In the Cornell studies careful records of the ancestry of each chick were kept and, because sanitation was dispensed with, exposure was natural but adequate as proved by the high death rate of susceptible birds. The environment of all birds was the same. The basis of selection for resistance was to include in the breeding program only those sires and dams proved to be productive of the most resistant families. The strains used were Leghorns that had been bred for high egg production followed by selection of family lines without inbreeding.

An original loss of 14.6 percent from lymphomatosis occurred at the beginning of the study. By the tenth generation, however, losses in the selected resistant lines had decreased to 8.3 and 7.9 percent whereas in the susceptible line they had gradually increased to 34.9 percent in the same generation. Mortality from all causes was 66.8 percent in the first generation but was decreased by ⅔ in the tenth generation. These losses were based on all populations involved, but the New York workers further discovered that by using proven sires the losses from lymphomatosis can be reduced below 5 percent, which is relatively unimportant. This genetic improvement in disease resistance occurred along with increases in body size and egg size and in the average number of eggs per hen. The study has opened the way to the production of disease-resistant stock males that can be sent out each year to producers and especially to hatcherymen.

As a result of such investigations many strains of longer-lived birds are now in commercial production, thus rendering the poultry venture more profitable through an increased income during the best year of the hen's life, as well as through a saving in the feed bill.

As previously mentioned, a problem such as this has many ramifications, not the least of which lies in breed differences. Contributions along related lines of research but under different conditions have also come from experiment stations in Louisiana, New York, and other States. The problems are not all solved; for instance it would be highly desirably to know the nature of the units of inheritance responsible for passing livability from one generation to another and what happens when this character is suddenly lost by an apparently resistant line.

RELATION OF EGG PRODUCTION TO GOOD HATCHABILITY

High-laying strains of fowls have been developed in most of our breeds, but the rapid growth of the broiler industry has emphasized the importance of eggs high in hatchability and productive of sturdy chicks. Commercial hatcheries which produced over 516,000,000 chicks in 1931 turned out more than 1,620,000,000 chicks in 1945. When it is realized that sometimes as high as 50 percent of the eggs placed in incubators fail to produce live chicks and that eggs for hatching usually cost more, it can be seen at once that large losses both in money and in inefficient use of equipment inevitably follow such a condition.

Many problems are concerned with an egg that will hatch well. It may be fertile and develop an embryo but because of some inherited character something happens to the developing chick which causes prehatching death, or weakens it after emergence from the egg.

Various studies carried on at the experiment stations have demonstrated that good hatchability is an inherited trait, but that in spite of good inheritance other problems arise. With the trend toward intensive systems of flock management, nutritional factors were found important in maintaining health and egg production. Although larger and larger numbers of hatching eggs began to appear under these more efficient management methods, poultrymen nevertheless soon noticed a reduction in the hatchability of the eggs. Thus it was only natural that investigations of the nutritional effects on the egg were soon under way.

As an illustration of the effect of diet on the hatchability of the eggs produced, certatin studies by the Wisconsin station are cited. These workers had observed that many fully developed but unhatched chicks presented symptoms indicative of an abnormal condition of the nerves. Earlier nutritional studies on growing and adult birds had associated some of these symptoms with deficiencies in certain of the vitamins.

The aim of one particular study was to establish what happens to hatching eggs when the vitamin biotin is lacking from the diet of laying hens fed all other known nutrients in adequate amounts. The hatchability of eggs from these hens was found to decrease to zero by the end of the second week, at which time they had used up their reserve stores of this vitamin. Chicks from eggs that did hatch during this depletion period exhibited many characteristic and highly abnormal nervous symptoms. In other chicks, free from such symptoms, there appeared definite abnormalities of legs and joints, and in none of the hatched chicks were strong vigorous birds produced. On the other hand, those derived from hens receiving the added biotin were normal in all respects.

As a result of such studies the manufacturers are now able to combine in their feed mixtures those natural materials rich in the principles now known to be necessary—and with marked improvement both in hatchability and in the condition of the chicks themselves.

But the nutritional problems are by no means fully solved. The experiment stations in Maine, Maryland, and New York are working on other vitamins and their relationship to the general dietary picture. Still other stations, particularly in California, are studying the amino acid relationships; South Dakota is investigating the influence of crop

plant sources; and from Ohio studies come indications that eggshell quality and shell color may be related to hatchability.

That the ramifications of this particular problem of high egg production and hatchability are many is self evident. Its seriousness is still such that some of the Northeastern States have planned a cooperative attack on the problem under the new funds made available by the Research and Marketing Act.

The two lines of research just discussed constitute by no means the whole story of problems now facing the poultry industry. Space limits prevent other than mentioning that excellent results are being obtained in developing more satisfactory birds for the broiler trade—a business that in 1945 produced a gross farm income of $279,146,000—and solutions are on the way for many problems confronting the turkey producers whose volume of business is of similar magnitude. In these fields also, fertility and hatchability problems dominate.

VETERINARY RESEARCH

The field of veterinary research is broad, dipping intimately into and affecting almost every phase of human endeavor. With this, as with all other phases of research, the process of studying methods and procedures for maintaining animal health is tedious, painstaking, and never ending. Whenever an "outstanding" achievement is announced one accepts it as just that, an achievement, realizing that much effort has gone into its attainment but at the same time that more remains yet to be done because of new problems opened up along the way.

During the 1947 fiscal year many worth-while contributions were made in the field of veterinary science and numerous articles—both popular and technical—have taken the results directly to those most interested. A few examples of these worth-while accomplishments in veterinary research follow.

SWINE DYSENTERY CAUSED BY NEW BACTERIUM

Swine dysentery was first described more than 20 years ago by workers at the Indiana station as an acute, highly fatal disease affecting chiefly young swine and characterized by a bloody diarrhea. The disease may appear soon after introducing new swine or cattle into a herd. In field experience it has occurred within a week or 10 days after immunization against hog cholera, much to the unwarranted embarrassment of the practicing veterinarian and distress of the owner. During outbreaks on farms, veterinarians specializing in swine diseases have often been called upon to confirm the diagnosis of swine dysentery in hundreds of animals in a single area.

Progress has been slow in the recognition, control, and prevention of the disease because until recently the specific cause was unknown. At a recent meeting of the American Veterinary Medical Association the Indiana workers reported that a new bacterium—a vibrio—had been obtained in apparently pure culture from the lining of the large intestine of a pig spontaneously infected with dysentery. In cultures, it somewhat resembled an organism found associated with certain cases of infectious abortion in cattle and thought to be the cause. In 6 different experiments, a total of 60 pigs were fed pure cultures of the

swine bacterium mixed with mucin. Typical symptoms of dysentery developed in 5 out of 6 of these experiments, but none of the uninoculated control animals contracted the disease. Because it was isolated from the colon or large intestine, the new bacterium has been named *Vibrio coli.*

At last, with the discovery of successful artificial cultivation of the organism causing swine dysentery, the way has now opened up for further steps, which should lead to eventual control of the disease.

NEW SYMPTOMS OF FOWL PARALYSIS

Fowl paralysis first made its appearance in this country about 1920 and since that time has attained the questionable distinction of causing about half the annual losses from diseases of poultry. A more acceptable term, which includes other forms of the disease as well as paralysis, is "avian leukosis complex." A dozen or more types are comprised in this complex, each bearing a descriptive name according to the organ or tissue involved.

Progress in preventing or controlling the disease is necessarily slow because of a lack of specific knowledge as to what causes it and how it is spread. Furthermore, recognition of the various types represented in the complex is highly important in mapping out and checking its spread. Just recently, workers at the Missouri station announced that birds with permanently soiled fronts (damp and darkened just under the beak, down the neck, and in the region of the crop) are victims of a form of the avian leukosis complex; this diagnosis also is probably true for birds carrying wilted combs. These heretofore unreported symptoms of the disease complex were observed in birds after experimental intravenous injections of blood in transmission trials with fowl paralysis.

Such findings are of great practical value, enabling flocks to be culled more closely for elimination of avian leukosis—an economic hurdle important to the whole poultry industry.

NEWCASTLE DISEASE A THREAT TO POULTRY RAISING

Newcastle disease, a relatively new virus infection of poultry, is now considered to have made its appearance in California more than 10 years ago, although it was not until 1944 that the disease was positively identified as such. Since that time it has swept the country and is now a serious threat to the economic structure of the entire poultry industry; from trivial proportions, the death losses from this disease have sometimes ranged up even to 95 percent. Efforts to control its spread have been of little avail in the past because of a lack of information as to the habits of the causative agent and methods of combating it. The disease has now attained the proportions of a national menace to the poultry industry.

Groups comprising the most outstanding scientists in the field of poultry pathology are concentrating investigations on various phases of the study of Newcastle disease to determine how to develop an effective vaccine, by what means the disease is spread, what methods of diagnosis are most accurate, how long premises must stand idle after an outbreak before restocking, what disinfectants are effective, what treatments will bring about recovery, and what possibility there is for spread of the disease through hatcheries. These and many other

questions concerning Newcastle disease must be answered quickly and accurately—and it is teamwork investigations supported by Federal-grant funds that aid in making such answers possible.

Workers at the Maryland station recently reported the production of a modified Newcastle virus by inoculation directly into the brain of a rodent—the Syrian hamster. The virus so handled is reduced in virulence and may be used for preparing vaccines which, after 30 days, completely protect chickens upon pen exposure to infection.

A useful method of differentiating between infectious bronchitis and Newcastle disease has been developed by the Rhode Island station. When infectious bronchitis virus is inoculated into the allantoic cavity of incubating eggs, a noticeable dwarfing of the embryo without death occurs; similar inoculations with the virus of Newcastle disease produce death without dwarfing. In view of the widespread interest and considerable volume of research on Newcastle disease, this finding should prove most valuable as a quick aid in diagnosing and differentiating between infectious bronchitis and Newcastle disease.

A SAFER VACCINE FOR BRUCELLOSIS

A tremendous need exists for a killed or greatly attenuated vaccine which is at the same time effective for preventing brucellosis Bang's disease) in all types of livestock. Sufficient has been written concerning this disease during the past 15 years to acquaint the public fully with its ravages among the lower animals as well as in man. Anyone who has once encountered the disease readily appreciates what is covered under clinical symptoms by such terms as weakness, sweating, chills, pain, and loss of weight. The farmer who has fought Bang's disease among his dairy cattle, or because of it is suffering economic setbacks in his swine herd, likewise appreciates the meaning of brucellosis and the need for preventive and curative agents and procedures.

According to workers at the Michigan station human infections arise from animal sources but rarely if ever from human cases or carriers. When one considers that *Brucella*—the micro-organism causing brucellosis—may penetrate the normal or minutely abraded skin, the following recent note in *Veterinary Medicine*, referring to the incidence of infection in swine is of considerable importance:

> From 1 to 3 percent of the swine slaughtered in our packing houses have brucellosis. Sometimes this disease does not harm and causes no economic loss; sometimes it destroys all chance of profit from the herd.

At the Michigan station one of the mucoid phases of the swine strain of *Brucella*, prepared as a live-cell suspension vaccine, was found to immunize guinea pigs and cattle against brucellosis. Better still, when the same cell suspension was nearly 100-percent killed by ultraviolet light and then injected into guinea pigs, a high degree of immunity against infection was produced. This finding is important and represents a stride in the right direction, in that it makes possible the use of a killed, and thus safer, product in the place of one which is living though presumably greatly reduced or apparently lacking in virulence.

DEATH LOSSES REDUCED IN FEEDER LAMBS

According to workers at the Colorado station, enterotoxemia ("overeating disease") gives rise to greater losses of lambs in Colorado feed lots than all other causes combined, instances of mortality not uncommonly reaching 5 percent or more. Although most workers agree that such deaths are caused by the toxins produced by an anerobic bacterium (*Colostridium perfringens* type D) further adequately controlled tests will be necessary definitely to decide this question. Regardless of cause, however, the Colorado station reports that in experiments comprising 1,200 feed-lot lambs in 1946, death losses from enterotoxemia of more than 11 percent in the lots self-fed on grain and alfalfa hay were reduced to less than 1 percent in similar lots receiving two-thirds of an ounce of sulfur daily; this was confirmatory of the previous year's findings. Sulfur failed to affect the rate or cost of gain or the grade or flavor of the meat. By following this practice the industry should save many thousands of dollars each year; in fact, one feeder of 20,000 lambs estimates that he saved 200 lambs by the supplementary feeding of sulfur.

CAUSE OF CALF DIPHTHERIA ELUCIDATED

Wyoming and adjoining States have experienced severe outbreaks of calf diphtheria—usually in suckling calves but at times also including mature animals. This is an acute infectious disease, characterized by the formation of certain lesions (false membranes) on the lining of the mouth and throat. A thread bacterium, *Actinomyces necrophorus*, was consistently isolated by the Wyoming station from typical lesions of calf diphtheria, but always associated with other micro-organisms which by themselves appeared harmless; working together with *A. necrophorus*, however, they produced typical lesions of this disease in experimental animals. Marked vitamin deficiencies were also found to increase the severity of the lesions observed.

Other disease conditions which appear to be caused primarily by *Actinomyces necrophorus* infection are constantly responsible for losses in Wyoming livestock. The problem here is not merely one of calf diphtheria, but is a general problem of abscess formation and pneumonia in sheep, elk, deer, hogs, and other animals, as well as in cattle. Although the actual number of deaths is large, the financial losses from animals which are merely sick are even greater.

The Wyoming station is pursuing this study in a vigorous manner in the hope of developing preventive and curative procedures of practical merit.

PARASITE CONTROL IN HORSES AND MULES

The Louisiana station reports the whole problem of gastro-intestinal parasites to be highly important because of the general animal husbandry practices known to prevail. Although parasitism predisposes to other diseases and may even be the primary cause of some deaths, this program was evaluated mainly in terms of work days saved and feed costs reduced.

During the course of this study it was found that phenothiazine destroys the red blood cells, particularly in horses and mules in poor con-

dition or on inadequate rations such as white corn and grass hay; treatment of such animals with phenothiazine is considered very risky. It was also determined that horses fail to tolerate the phenothiazine as well as mules. Phenothiazine in combination with carbon-tetrachloride, removed a higher percentage of all parasites than did phenothiazine alone. Furthermore, colic occurred less frequently in treated than in untreated animals.

As a result of this investigation it is estimated that 2,500,000 work days per year are saved in Louisiana by regular treatment of horses and mules for internal parasites. It is further estimated that from $2,500,000 to $3,000,000 are saved by farmers in reduced feeding costs and lower incidence of colic as well as of diseases in which heavy parasitism plays a predisposing role.

MASTITIS—GREATEST SCOURGE OF THE DAIRY INDUSTRY

Infectious mastitis has been recognized as the greatest scourge of the dairy industry since 1884. As of January 1, 1942, a conservative estimate of annual losses resulting from mastitis in the United States is $19,000,000; other estimates suggest that at least a fourth of all our dairy cattle are infected.

This disease is the subject of numerous investigations over the country, and as time goes on bits of the jigsaw puzzle that is mastitis begin to fall into place. Eventually the picture will take shape and, as a result, we may come to visualize adequate methods of prevention, control, and treatment of this menacing disease.

Control or treatment of bovine mastitis has been materially advanced by findings of the California station, where it was determined that treatment with penicillin is more effective against the staphylococcic form when used during the dry period rather than during lactation. This was also found true by the Connecticut (Storrs) station working with streptococcic mastitis in cows; these workers estimated an annual saving of $252,000 in 605 herds under their supervision during a mastitis-control program. The savings result from increased milk yields and decreased numbers of cows slaughtered because of infection.

Recovery of streptococci from the surface of teats as long as 5 days after the final milking previous to a dry period was an indication to workers at the Virginia station that these organisms may become a part of the surface flora on the teats of hand-milked cows. This information indicates that currently recommended preventive measures would be inadequate to control this way of spreading infection.

During its investigations of mastitis the Michigan station was called upon to help solve the mystery in a small dairy where the properly pasteurized milk had increased in bacterial counts over a 4-month period from a normal level of 15,000 to as high as 2,500,000 on some days. Despite careful cleaning and sanitizing of the dairy these high counts continued until the source of contamination was finally located and eliminated. It turned out that 1 of the 7 producers whose milk was handled by this dairy had contributed milk containing heat-resistant strains of bacteria. An unclean milking machine harboring these heat-resistant forms was spreading them into the milk during the process of milking and at the same time inoculating

the udders of the cows. Even after the milking equipment had been specially cleaned and sanitized to prevent further spread, it took from 1 to 4 months for infected animals to rid themselves of these bacteria.

PROGRESS IN AGRICULTURAL ENGINEERING

The present high state of our national agriculture has been achieved largely as a result of coordinated teamwork in scientific research—teamwork that involves the blending of applicable fundamental knowledge gleaned from the contributions of all science into a more economical and practical attack on the particular problems at hand. Each underlying principle or discovery, even though its connection at the time may not seem apparent, may eventually contribute to and dovetail into the pattern of a fuller knowledge and understanding of how the farmers' needs may be met.

Agricultural engineers have long held an important position in the weaving together of these complex linkages into our present concepts of farm problems and situations. They have used not only their own knowledge and understanding of engineering principles but have brought into the picture the discoveries and contributions of other scientific workers as well as the practical observations of those farmers who have appreciated the functional requirements upon which the success of a new engineering method or appliance must depend.

As illustrating the combined scientific approach to problems involved in the complex agriculture of today the current research programs on cotton provide a good example. In order to obtain an ample supply of better kinds of cotton fiber, the geneticists are developing varieties that produce good yields of the types of fiber now demanded by industry. They are also incorporating into these varieties certain characteristics for resistance to disease and for plant conformation adapting them to modern methods of harvesting and ginning.

The agricultural engineers are involved in the designing of seedbeds suitable for proper operation of the new machines they have built to grow and harvest the crop, as well as in the developing of new and improved equipment and processes for ginning, cleaning, and compressing the fiber.

Furthermore, the workers in one group may help to solve certain problems that have involved workers in other groups. For example, a long-recognized engineering problem in the cleaning of mechanically harvested cotton has been the removal of the leaves that are picked along with the seed and fiber. The cotton breeders are now producing varieties which, along with other desirable characteristics, possess glossy leaves that do not stick to the fibers during the harvesting operations. Such cotton enables the cleaning mechanism to do the job more effectively and at less cost.

PROGRESS IN IRRIGATION TECHNIQUES

Irrigation in the United States was brought into being over 100 years ago when the early pioneer plowed a furrow from a flowing stream, thus diverting water to moisten the soil before he planted his crop and later on to sustain it under arid conditions and so assure a fuller harvest. As the acres under irrigation increased because of

the need for greater farm production in these fast developing areas, many complex problems relating to the use of both land and water were constantly coming to attention. However, it was nearly 50 years after the beginnings of irrigation before organized research along these lines was attempted.

In 1940, according to the U. S. Census of Irrigation, 21,175,963 acres were under irrigation. Of this grand total, 19,903,381 acres were located in the 17 Western States, 1,100,358 acres in Arkansas and Louisiana, and 172,224 acres in the remaining 29 States.

Among unanswered questions posed to the agricultural engineer were the following: What are the sources of water and how can they be maintained to deliver a full season's supply? What are the water requirements for full production of different crops? What are the best practices for applying water so that soil, water, and plant relationships can be maintained in proper balance? How does water flow? What are the best methods for water conservation and its control to assure equitable and economic application to growing crops? How can land areas be brought back to full production when they have become nonproductive from waterlogging or excessive accumulation of toxic salts?

The agricultural experiment stations, in cooperation with the Department, have made great strides toward a fuller understanding and solution of some of these basic problems. However, much remains to be done before land and water resources can be fully utilized in the development and maintenance of a permanent and profitable agriculture. Special facilities have been set up in the State experiment stations to study at first hand some of the underlying principles in the flow and distribution of water.

Typical of results are the developments by the California and Colorado stations of structures and equipment for measuring the amount of irrigation water applied to crops; these are the Parshall-flume and the portable field meter which, more than any previous devices, have overcome the difficulties involved. In fact, the Parshall-flume is now generally recognized as a standard for measuring water in irrigation channels.

The Wisconsin, California, and Oregon stations have contributed adaptations of sprinkler irrigation to the growing of crops, together with designs of apparatus for determining soil moisture conditions. These findings have also added to a fuller understanding of irrigation problems and have contributed to the conservation of water.

The Utah station's fundamental work on canal linings for main ditches and laterals, together with the establishment of basic information on proper spacing, depth, and size of tile drains necessary to prevent waterlogging of irrigated soils, have contributed much toward increasing the efficient use of water.

In the field of forecasting for annual irrigation water supplies the development of techniques for measuring snow cover by the experiment stations in California, Montana, Utah, and Arizona, in cooperation with the Department, as well as the measurement and fuller understanding of the recharge characteristics of underground water storages by the stations in Arizona, Arkansas, and Louisiana, have progressed to the point where the amount of seasonal water supply

available for crops in these areas can now be predicted with great accuracy.

The results of studies on the water resources available to the rice area of Arkansas have led to the conservation of ground-water supplies and to the adoption of more efficient methods of irrigation and surface water use to supplement them. Some 15,000 acres in the State are now estimated to be irrigated from surface water as a result of these studies—and this acreage is rapidly on the increase. Net savings of $4.50 per acre when surface reservoirs rather than wells were used for irrigation have been reported, resulting in an annual saving of $67,000 to the rice growers of Arkansas. Moreover, the farmers who irrigate with surface water have reported increased yields of 7.5 to 12 bushels of rice per acre from this practice; at current prices this means an additional income of around $262,000 annually.

Such examples represent only a few of the contributions already made toward a fuller understanding of the complicated processes involved in the proper use of water for producing crops. Much more work remains to be done. For example, preliminary studies have shown irrigation to be of great value in the production of certain crops under humid conditions. This problem is beginning to receive consideration at many of the stations.

ENGINEERS HELP PRODUCE MORE MEAT

The constant plea during the war and postwar years for a greater output of foodstuffs, coupled with the needed economy in production, has caused the agricultural engineers of the Oklahoma and Texas stations to look into the possibility of increasing the forage production from grazing lands. Thousands of acres in these two States are covered with scrub-oak, sagebrush, mesquite, and other woody species interspersed with scattered growths of natural range grasses. Such lands have provided year-round grazing for approximately one animal to each 15 acres.

Range farmers have long appreciated the fact that if methods and machinery could be devised for the economical eradication and disposition of competitive and nonproductive tree and shrub growths on such lands, the natural processes of reseeding from the desirable range plants would take place and soon provide an increase in the annual carrying capacity. Research designed to attack this general problem has progressed to the point where its solution can now be assured.

The engineering approach has been directed toward the development of new and the adaptation of old machinery and methods to the problem at hand. The simple use of a steel cable attached between the drawbars of two tractors in parallel movement across the land for uprooting many of the shallow-rooted shrubs and trees is one method of attack that has been successful under favorable conditions. Furthermore, the development of machinery such as small portable saws (adjustable for vertical or horizontal action), brush cutters, brush beaters, power-brush mowers, and power-lift buckrakes for gathering together and removing cut materials from the land have all proved very satisfactory in actual use.

Two general requirements have had to be satisfied in these over-all undertakings, namely, the development of machines that are not only sturdy but that are also economic in operation. Preliminary results on the response of grass to land clearing indicate a twofold to fivefold increase in growth densities following such operations. Thus the same land area that in years past produced only 300 pounds of beef per year now provides carrying capacities capable of producing 600 to as high as 1,500 pounds.

The ultimate in practical machinery and methods for this big job are not as yet in sight; in these preliminary studies, however, proof has been given that still better equipment can be developed and that the resultant decreased cost of clearing this type of land will continue to pay large dividends on the original investment in research.

FLAME CULTIVATORS FOR WEED CONTROL

In the production of row crops, competition with weeds has emphasized the need for developing implements to remove them. The simple hoe, multiple shovel cultivator, spring-tooth harrow, and the rolling disk with its adaptation to special weeding problems are typical of such developments, and all of them involve the replacing of human energy by machines. Each of these appliances has done a good job, in its way, but increasing pressures for all-out production have shown that in one or another aspect they all are lacking.

Cotton and sugarcane are two crops in the South that still require much hand hoeing to assure the maximum in production. Agricultural engineers of the Mississippi, Louisiana, and Arkansas stations, in cooperation with the Department, have been especially concerned with this restraint on production and for a number of years have been seeking ways to overcome it.

Early work by others, using gasoline and kerosene to operate simple burners, showed that when a soil is treated by flaming, the subsequent development of weeds is delayed but not stopped. The station and Department investigations as to the reasons for such a reaction revealed that surface seeds are killed by the flame and that all later weed growth arises from seeds which were below the surface affected by the heat. Since potentialities of the method were immediately apparent, efforts were soon directed toward the development of special burners which could be rendered mobile for economically wide areas of ground; in this way flame cultivation or weeding was born and is today being actively developed.

Tests with experimental flame cultivators on growing crops have shown that $3.60 per acre in the case of cotton and $3.00 per acre in the case of sugarcane can be saved by flame cultivation over the costs for hand hoeing. One other special adaptation of the flaming principle which has proved satisfactory is the development by Mississippi station workers of a special burner to clean spoil banks and drainage ditches of weeds and other plant growths. This mobile unit operates at speeds of 2 to 3 miles per hour, does a better job than that by hand methods, and costs less. The engineers have also adapted the flame cultivator to the expensive hand job of chopping or thinning out certain crops by devising special attachments that allow the operation to be performed automatically as the machine is drawn across the field.

This supplemental report by no means infers that all research on this new principle in farming operations has been completed, since much yet remains to be done to assure properly functioning machines that may be easily adapted to many specific problems. More experimentation is also needed to determine the heat tolerances of different kinds of plants so that special burners can be devised for eliminating weeds from particular crops.

GRAIN-CONDITIONING STUDIES

The occurrence of high-moisture corn in some localities of the United States every year gave early stimulation to the demand for practical information on drying or otherwise conditioning the crop. In attempting to find solutions of this problem, the experiment stations, in cooperation with the Department, designed and set up research studies throughout the grain-producing regions of the country in order to evaluate the factors influencing storage and drying and to determine proper methods of handling, feeding, storing, and conditioning corn and other grains as well.

The results of this work over nearly 3 decades have established definite answers to many of the functional elements involved, but further research is needed for the complete understanding that will lead to practical and economic recommendations. We now know, for example, that safe storage requires that kernel moisture in ear corn must be brought down to 20 percent or less and that shelled corn should be under 13 percent. Detailed studies of the use of supplemental heat in drying operations have also been made and rates of drying have been measured for a large number of drying conditions. Relationships between relative humidity and temperature are also well established. In short, enough evidence has been established to show the practicability of conditioning corn and grains and to furnish a guide to designs for developing the necessary equipment.

The Iowa and Illinois stations with the Department have this year completed a series of tests that evaluate the factors influencing the storage and drying of corn; these results have led to the development of a new and valuable method of calculating changes in corn moisture content when the air temperature, relative humidity, and rate of air flow are known. This information, together with other contributions to the problem obtained over the years, provides a scientific basis for design and operation of corn-drying equipment that should be readily adaptable to similar problems involved in the drying of other grains.

Experimental corn- and grain-drying appliances designed on the basis of these accumulated researches have been developed, and preliminary trials show that they do the job well even though not yet as economically as might be desired. Fundamental investigations on this problem so important to the farmer and on its potential contributions to national agriculture are therefore still being continued.

HAY-DRYING STUDIES

Considerable progress has been made by many of the State experiment stations in the development of equipment and techniques for hay drying, which involve both field and barn procedures. An important step in meeting the forage curing and storage problem under the

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climatic conditions existing in Alaska has been made in studies summarized this year by the Alaska station. This work indicates that mow-curing of hay in the Matanuska Valley is entirely feasible and practical either for grass-legume mixed hay cut during July or for oats-pea hay cut in the fall. Grass-legume hay from the same field was higher in quality when mow-cured than when field-cured, in that it had a much greener color, was not dusty, and had no loss of leaves. Oats-pea hay placed in the mow at a moisture content of 59 percent after swath-curing for 72 hours in the field completed the curing process satisfactorily and resulted in a good quality product. This hay was greener in color and had retained much more of the finer stems and leaves than had the field-cured oats-pea hay.

The cost of cutting, raking, loading, and placing in the mow, including the cost of the electric current used, amounted to $9.20 per ton for the mow-cured lot, as compared with a cost of $9.90 per ton for cutting, raking, placing on stakes, and later hauling to the barn for the field-cured hay. These preliminary results therefore indicate that by use of the mow-curing method high-quality forage can be provided at a cost not in excess of that produced by ordinary field-curing in Alaska and further that this procedure minimizes the weather risks involved in outdoor haying operations.

RICE-DRYING STUDIES

Introduction of the combine into the southern rice-producing areas for a fuller mechanization of growing and producing this crop called attention to the need for developing techniques and equipment for drying the grain to minimize cracking and assure safe storage.

Results reported by the Arkansas station indicate that the cost of harvesting the crop by former binding and threshing methods is approximately 29 cents a bushel, compared with 23 cents a bushel for combining and drying—or a net saving to the grower of 6 cents a bushel for the newer methods. This year approximately half the crop grown in Arkansas was combined and dried, and as the machines become more widely available larger proportions of the rice in the State will be handled in this manner. On the basis of a crop of 10,000,000 bushels harvested by combine a net saving to Arkansas growers of $600,000 would be obtained. This figure does not include the additional saving of 3 to 4 bushels of rice per acre that were formerly lost in the usual processes of binding and threshing, nor does it include the increased value of the land for pasturage, the returning of organic matter to the soil, and the improved milling qualities resulting from the combining and drying operations.

But still the research picture is incomplete. Among other things, future studies will include determinations of proper drying temperatures for the several varieties grown, improvements in harvesting and drying equipment, and the development of field techniques that will contribute further to lowering the costs of production and handling of the crop.

A NEW STRUCTURE FOR POTATO STORAGE

Proper storage of our large annual potato crop to assure better quality and flavor for late-season consumption and the problems involved in reducing losses under storage conditions have prompted

the initiation of many cooperative research undertakings between the States and the Department.

In the past the growers and warehousemen who have operated ordinary storages for potatoes have found that if the air within the structures is too dry the tubers lose too much water and become shriveled, whereas if it is too humid the storage house deteriorates rapidly because of the excess condensation.

Cooperative engineering studies between the Department and the experiment stations in Colorado, Maine, Michigan, North Dakota, and Nebraska have resulted in the development of a "shell cooling" principle that has been successfully adapted to the designs for new storage-building construction. Essentially the principle is a provision which allows cool air to circulate through well-insulated ducts in the walls and floors of the structure while at the same time the air in contact with the potatoes is relatively higher in humidity.

Extensive tests with large bins in experimental structures have shown that the circulation of cool air under and behind the bins by gravity or by thermostat-controlled forced-air systems is effective in removing the excess heat given off by the tubers and that proper storage temperatures and humidity can be maintained.

Shrinking, sprouting, and general deterioration losses of the stored tubers were from 1 to 10 percent lower than when old types of structures were used. Furthermore, the new type of building can be expected to last longer because the air flow in the shell prevents accumulation of the condensed moisture that causes deterioration of the structural parts. The new storage house is now being widely adopted in the principal potato-growing regions of this country.

FOODS, NUTRITION, AND FARM HOUSING

Progress in research, as in other fields of endeavor, is reckoned from some reference point. For a considerable number of the food and nutrition investigations of the State agricultural experiment stations, a pertinent point of reference is the organization of the National Cooperative Project Conservation of the Nutritive Value of Foods. This research program was initiated in 1942 as a contribution to the war effort and in specific response to recommendations of the National Nutrition Conference for Defense held at the call of the President in May 1941. The particular recommendation that gave impetus to the original organization and subsequent development of this cooperative research program was that there be "vigorous and continuous research to add to our present knowledge of the nutritional needs of individuals, the nutritional status of groups in the population, the nutritive content of everyday foods, and the effects of various methods of production, processing, storing, and cooking on their nutritive value."

The National Cooperative Project—organized on a coordinated basis among the agricultural experiment stations with as many as 42 participating in studies on at least 65 commodities—was conducted intensively to determine the nutritive value of foods, particularly the vitamin values, the factors affecting these values, and ways to conserve them. Early in the course of this cooperative study emphasis was placed on foods commonly used and widely produced and the data, as obtained, were made immediately available in preliminary

form for use in planning the food supply of the armed forces. It was recognized, however, that the information was equally valuable in planning for the adequate food supply and nutrition of individuals and of population groups. As the work continued, investigations were undertaken on certain other foods that were of local or regional importance, or that gave promise as home-garden crops for meeting local nutritional needs.

Many of the findings under this cooperative research have now been published, including, to date, more than 250 such reports dealing with particular phases of the cooperative investigation. The individual reports have dealt not only with the findings on nutritive value, but have included related studies that were necessary to insure sound research. These related studies, concerned with the review of previous work, adequate sampling methods, analytical procedures, calculation of results, and the need for certain replication and repetition to establish the extent or the reason for variation, have already been discussed in part in the 1946 Report under a consideration of the research method. In addition to these individual reports, it is the intent, insofar as possible, to present under a single cover a well-rounded picture of the cooperative investigations on each commodity studied.

An example of this effort is to be found in the progress made within the year by the key commodity chairman (Minnesota) and collaborators in assembling, evaluating, and presenting the findings from the 12 experiment stations (Alabama, Idaho, Illinois, Maine, Minnesota, Mississippi, Nebraska, North Carolina, North Dakota, Oklahoma, Tennessee, and Texas) and the Department cooperating in investigations of factors influencing the nutritive value of potatoes. The original manuscript is now in process of revision and awaits the completion of certain pieces of research necessary to round out the study.

Some, but by no means all, of the studies initiated as part of the National Cooperative Project have been suspended, the original objective having been accomplished, or new lines of investigation having been suggested by findings obtained as the research progressed. Typical of the accomplishments in the course of this cooperative effort, are the results of certain phases of the work rounded out within the past year and summarized briefly in the following paragraphs.

VITAMIN VALUES OF CARROTS, AS INFLUENCED BY PRODUCTION, STORAGE, AND COOKING

As its part in the study of the nutritive value of carrots, the New Mexico Station, particularly in coordination with other investigators in the western region, undertook to determine the effects of storage and of different methods of cooking on the carotene and ascorbic acid content of carrots. This study was considered essential since most of the vitamin values for carrots available when the work was initiated in 1942 were based on the freshly harvested raw product. These values, it was appreciated, would not give a true picture when used to calculate dietaries for the armed forces or for other groups of people, because such data failed to account for losses during transportation, storage, and preparation for the table.

No loss of carotene was found to occur during storage as long as the carrots remained edible: this held true whether they were stored

with or without tops, and whether they were held in a commercial warehouse, in a household refrigerator under different conditions, in pit storage, or were left in the field all winter. In storage, however, there was a loss of ascorbic acid, the greatest loss occurring immediately after the carrots were harvested: following this, there was a slow and gradual decline. Cooking was found to cause only negligible losses of carotene, but losses of ascorbic acid were appreciable, ranging from 8 to 40 percent or more and depending on such factors as amount of water, cooking time, etc. Use of the pressure saucepan for cooking resulted in the greatest retention of ascorbic acid. Grating of raw carrots, commonly practiced in the preparation of salads, likewise resulted in almost immediate loss of approximately 50 percent of the reduced ascorbic acid.

These losses in ascorbic acid prompted an incidental study pertinent to evaluating the true worth of the carrots as a source of this vitamin. The usual chemical method for determining ascorbic acid in foods measures only the portion that exists in the reduced form, this being the form largely present in raw foods. The reduced form is rather easily oxidized to what is known as dehydroascorbic acid, a form still available to the human body but detected only by a special method of analysis. A more thorough study of the ascorbic acid losses showed that a part of the apparent decrease of the vitamin in the cooking and grating of carrots was due to a change to the dehydro form. Actually, therefore, the cooking and grating losses, as far as the body was concerned, were not a great as routine analyses indicated.

Another phase of investigation undertaken as part of the study was that of determining the vitamin values and their variation in the raw carrots. Obviously, values for the raw carrots had to be obtained as a base line before storage or cooking losses could be calculated. It was appreciated that there would be a range in values for the raw carrots, particularly if more than one variety were used and if the tests were carried out on lots of differing origin.

The early observations indicated the desirability of carrying the tests over several growing seasons and with attention to the several variables concerned. This part of the study, incidental to the main objective of determining storage and cooking losses, was directed toward determining the extent and causes of natural variations in the vitamin values. The results obtained showed that carotene increased steadily as the root matured, but that the very high values of the spring carrots were not reached by the slower growing fall crop.

Ascorbic acid fluctuated from day to day and appeared to be affected by environmental conditions such as sunshine and irrigation. Highest ascorbic acid values were found in very young carrots; however, higher values than are usually reported were discovered in those roots grown at high altitude and under abundant sunshine.

BETTER NUTRITION FOR MAINE

Another investigation that fitted into the coordinated plan of the National Cooperative Project, was undertaken by the Maine station for developing means to improve the diets in the State, particualrly through the winter and early spring months. The need for this improvement had been brought out earlier in a study of the food habits

and physical condition of certain groups of grade-school children. It appeared from this study that the nutritive condition of Maine people would be improved through increased food production and conservation and by increased emphasis on the use of milk, eggs, whole grain, potatoes, fruits, and vegetables, particularly those rich in vitamin A and ascorbic acid. Toward meeting these recommendations, a study was undertaken to determine varietal differences in the ascorbic acid content of a number of vegetables that can be successfully grown in Maine and to determine the best methods for conserving the vitamins during cooking and canning.

Rather marked varietal differences were found in the ascorbic acid content of those vegetables ordinarily considered good sources of the vitamin. This, for example, was true for tomatoes, high and low ranking varieties tending to maintain their relative rank even though seasonal variations were also observed. When canned in glass and held in storage for 8 months the tomatoes lost anywhere from 14 to 49 percent of the ascorbic acid originally present in the raw product as canned. Tomatoes canned in tin lost a lower percentage of ascorbic acid than those canned in glass, but in either case varieties initially high in this vitamin lost a lower percentage than those which were initally low.

A canned mixture of tomatoes and green or red peppers was developed to give a product that contained considerably more ascorbic acid than the same variety of tomatoes canned alone. Of the other vegetables studied, cabbage, kale, peppers, rutabagas, turnip greens, and spinach proved to be very good sources of ascorbic acid, but green beans were low in this vitamin. The results of this investigation have been extensively used by the State Extension Service in teaching Maine people what varieties of vegetables to choose for high ascorbic acid content and how to conserve the vitamin during cooking and canning.

KALE—A RELIABLE SOURCE OF CAROTENE AND ASCORBIC ACID

Kale, recommended for use in improving Maine diets, was likewise recognized by the Delaware station as a hardy, leafy green vegetable that could be grown in home gardens to extend the supply of greens relied on to furnish ascorbic acid and carotene. A study of factors influencing the destruction of these vitamins in kale suggested first of all that home-garden plantings should be protected from frost, since growing kale hit by heavy frosts suffered serious losses of ascorbic acid and the vitamin was not reconstituted later upon cooking. In the holding of kale after harvest, a cool moist atmosphere proved best for retaining quality, palatability, and ascorbic acid content. Packing in chopped ice most adequately provided such conditions, the tests indicating that kale thus marketed would be a good buy for the consumer and a profit item for the retailer.

In cooking there was only small loss of carotene but loss of ascorbic acid was appreciable, increasing in magnitude with increased volume of cooking water, time, and exposure to the air. These results point to the nutritional advantage of cooking kale in a small amount of

water, preferably in a covered pan for as short a time as is consistent with attaining good texture. Vitamin losses in frozen kale were mainly associated with the blanching operation before freezing, the ascorbic acid loss being considerable, but that of carotene small. During frozen storage there was an insignificant change in ascorbic acid content, but a gradual loss of carotene.

CRUSHED-ICE REFRIGERATION OF VEGETABLES

The advantages of crushed-ice refrigeration noted in the Delaware tests with kale were likewise observed in experiments at the Ohio station to determine the effects of refrigeration on conservation of ascorbic acid and retention of weight in vegetables. The rate of loss of the vitamin during storage varied with the storage conditions. Cabbage, tomatoes, and green peppers retained 94, 88, and 85 percent of their original ascorbic acid content when stored in air at room temperature for 48 hours. All other vegetables studied retained much less of this vitamin. The same vegetables stored in crushed ice retained a greater percentage of their ascorbic acid than those stored in air at room temperature, on top of crushed ice, or in a refrigerator.

In addition, shrinkage losses, particularly in the green leafy vegetables, were greatly reduced by packing the freshly harvested products in crushed ice. For greatest retention of nutritive value and quality, emphasis is placed on the importance of packing the products in the crushed ice immediately upon harvest and of continuing proper refrigeration to the time of consumption.

PORK—A VALUABLE SOURCE OF DIETARY THIAMINE

Pork, because consumed in such large amounts and because extensively used after home preservation by curing or freezing, was selected as a commodity for study by several of the stations participating in the National Cooperative Project. Results recently summarized by the North Carolina and Washington stations, where the vitamin studies were initiated in conjunction with collateral work on rancidity problems, not only give pertinent information on the commodity but also indicate how important it is that difficult problems be studied with more than one approach and by more than one group of investigators.

Work on the vitamin content of pork at the North Carolina station showed this meat to be an excellent source of thiamine and apparently a fair source of riboflavin. Cooking did not greatly affect vitamin values, since loins roasted to an internal temperature of 85° C. retained approximately 80 percent of the riboflavin and 70 to 80 percent of the thiamine. In the course of these determinations the vitamin values were found to vary greatly in different carcasses, from muscle to muscle within the same carcass, and even from section to section of the same muscle. These results definitely establish the importance of carefully considering the matter of sampling in any study of vitamins in pork.

The Washington station, with due consideration to sampling techniques, also showed pork to be an outstanding source of thiamine. Special attention to the problem of riboflavin determination indicated

that procedures currently in use to liberate it from the tissues resulted in extraction of only a fraction of the riboflavin present in the raw pork. Enzymes in the meat itself were capable of liberating large additional quantities. These and other observations threw doubt on riboflavin values obtained on meats, and possibly other foods, by the currently used fluorometric and microbiological procedures of analysis and pointed to the need for further research on extraction methods before reliable values can be obtained.

The sampling and analytical difficulties such as brought to light by the North Carolina and Washington workers, as well as others, suggest the advisability of reevaluating some of the early data on pork. As in the present studies, this need for reevaluation of scientific data frequently occurs because problems arising during an investigation cannot always be foreseen, but are uncovered and eventually solved only by progressive and continuous research.

EGG PROTEINS HAVE HIGH NUTRITIVE VALUES

As one of its contributions to the National Cooperative Project, the Iowa station turned its attention to dehydrated eggs. To save shipping space this product was being packed in large quantity for use in the feeding of army and civilian groups in all parts of the world. As originally planned, the study was undertaken to determine whether dehydration and subsequent storage under good and even under unfavorable conditions caused any change in the nutritive value of the egg proteins. The first studies showed that drying of eggs had no effect on the nutritive value of their proteins. Digestibility decreased as the storage period lengthened but the nutritive value of the digestible portion did not change even after 1 year, although the eggs had by that time become inedible.

The study of protein quality was conducted by the classic nitrogen-balance method, nitrogen being the element particularly characteristic of protein. Unexpected findings in the course of the balance studies showed the fundamental concept that there was a constant level of break-down of body proteins (the so-called endogenous metabolism) when food nitrogen intake balanced body excretion of nitrogen; the balanced studies showed further that egg proteins spare tissue proteins and are more effective than the animal's own tissues in furnishing necessary chemical units for the animal's protein economy. These and other findings pointed the way to a new basis, namely, that of biological efficiency, for evaluating protein quality. This new concept of biological efficiency refers to the relative ability of the food nitrogen to spare body nitrogen.

A whole new field of investigation was opened up by the original work on the problem, and related studies were undertaken in an attempt to explain some of the unexpected experimental observations. The challenge to study anew the whole problem of protein needs and protein utilization of the body under various dietary conditions is being met through continued studies by the Iowa station and by many other interested investigators.

Pointing to the practical applications of this study, the Iowa station indicates that the particularly high nutritive values of the pro-

teins of eggs, dried and stored, and egg white and egg yoke have been established. New concepts of the fundamental nature of nitrogen metabolism and of the protein requirement have been developed and are important in nutritional planning for both military and civilian groups. The importance of including protein and increasing the calories in the rations of men living on survival rations has been emphasized.

The data obtained in the ramifications of this investigation emphasize also the importance of the relation of nutrients in the diet to each other, and should be of value in the interpretation of unexplained effects of various nutrients when diets of different fat content are employed. These data support work of others, indicating the need for reevaluating the practice of feeding low-fat rations to livestock; the findings also suggest important considerations that should be kept in mind whenever reducing diets are being planned.

LOW-COST FARM HOUSING—VIRGINIA SURVEY AND PLANS

Another field of investigation of very great current interest is that on farm housing. Although plans are now under way for carrying out researches on this problem, very little background information was at first available. Appreciating the need for such work, the Virginia station has investigated the possibilities of low-cost farm housing in that State. The need for this study was indicated particularly by the results of a survey conducted intensively in 10 Virginia counties in 1934. This survey revealed deplorable conditions, and the 1940 census confirmed them by showing a decline of $40,000,000 in the value of farm buildings of all kinds over a 10-year period.

Recent conditions reflected the deterioration and lack of repairs as well as the obsolescence of a large number of the farm homes. Farmers were interested in new construction and had been saving for it during the war; it was therefore felt that information for their guidance should be available whenever the movement for building started. In the interest of providing information of greatest use, a survey was undertaken in 1945 to determine what farm women wanted in their homes. The object was to analyze the functional requirements of low-cost farm homes, to translate these requirements into housing plans, and to determine types of materials and construction necessary to produce a low-cost house consistent with acceptable quality and durability and in line with the low income to support it.

This survey, planned and conducted by the State Extension Service in cooperation with the Virginia station, brought in completed questionnaires from 1,630 farm women. Their answers were tabulated and presented in a brief mimeographed report that was widely distributed for use by housing leaders in this and other States. It was clear that Virginia farm women have definite ideas of what they want in their homes as regards number of rooms, use of basement, storage, utilities planned, amount of new building, and extent of remodeling. Although their wants were not exactly a "minimum" that would contribute to low cost, the results are nevertheless considered very important as guides in planning farm homes and in influencing the women themselves toward more thorough thinking and planning.

The second objective of the study, namely, that of practical analysis of construction methods and plans is nearing completion; the findings will be presented in a bulletin to serve as an illustrated guide to farmers considering the building of new homes. The results of this survey have proved very useful in evaluating and influencing the plans for farm homes. For example, it had been considered feasible in producing low-cost farm homes to eliminate the basement and dining room. The survey made it apparent, however, that most farm women would not sanction the loss of these rooms, which must therefore now be considered in plans for new homes.

The guide is being planned to show many economies of construction that will save money and thus contribute to a general lowering of buildings costs. The Virginia workers concluded that in view of the current high construction costs and the ideals farm women have set, no really low-cost new housing may at present be possible. However, they offer the concept that the first cost of a home is not the only cost; construction permitting long years of useful life with small expense for repairs will result in lowered costs per year and thus ultimately in a low-cost building.

The results of this investigation are serving well as background and supporting information for a new study on the development of plans and designs for Virginia farm homes. This new research program will coordinate with a southern regional cooperative study now being organized to investigate household activities, facilities, and family preferences in the South as a basis for developing functional plans for rural housing.

STATISTICS—PERSONNEL, PUBLICATIONS, INCOME, AND EXPENDITURES

PERSONNEL AND PUBLICATIONS

The research personnel of the experiment stations in 1947 included 2,621 staff members devoting full time to station research and 2,669 who divided time between research and teaching or extension work. The total in both categories, 5,290, represented an increase of 916 over the total of 1946 and there were 432 more full-time workers in 1947.

Publications of the experiment stations in 1947 included 681 bulletins, circulars, and reports, 1,816 articles in scientific journals, and 663 miscellaneous publications. By comparison with 1946, the stations published 48 more bulletins, circulars, and reports, 39 fewer articles in scientific journals, and 23 more miscellaneous publications.

Data by individual States relating to personnel and publications are shown in table 1.

INCOME AND EXPENDITURES

Appropriations under the authorizations of the Hatch, Adams, and Purnell Acts for use by the experiment stations in 1947 totaled $4,542,500, each State receiving $90,000, and Alaska receiving $42,500. A total of $2,663,708 was appropriated under the Bankhead-Jones Act of June 29, 1935, with allotments to the individual States, Alaska, Hawaii, and Puerto Rico as shown in table 2. These allotments are made on the basis of rural population adjusted in accordance with the provisions of the Department of Agriculture Organic Act of 1944.

The total of Federal-grant research funds appropriated under all authorizations was $7,206,208, the same as in 1946.

Expenditures of Federal-grant funds are shown under object classes by individual experiment stations in tables 3, 4, 5, and 6, and expenditures of non-Federal funds in table 7. The 1947 expenditures of non-Federal funds which include State appropriations, research grants, and income from other sources totaled $27,669,999, as compared with $20,786,854 in 1946. The 1947 non-Federal fund expenditures by all of the stations approximated $3.84 for each $1 of Federal grants.

TABLE 1.—*Organization, personnel, and publications of the experiment stations for the year ended June 30, 1947*

Station	Date of legislative assent to Hatch Act	Date of organization under Hatch Act	Personnel					Publications					
			Full-time research	Research and teaching	Research and extension	Research, teaching, and extension	Total research workers	Station publications		Articles in scientific journals		Miscellaneous publications	
			Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Pages*	*Number*	*Pages*	*Number*	*Pages*
Alabama	Feb. 27, 1889	Apr. 1, 1888	55	34		1	90	23	244	14	87	7	33
Alaska	May 2, 1929	May 1, 1931	7	1	1		9						
Arizona	Mar. 19, 1889	July 1, 1889	21	36			57	10	377	14	110	5	30
Arkansas	Mar. 7, 1889	Apr. 2, 1888	19	33	1	1	54	9	193	10	52		
California	Mar. 12, 1889	Mar. 13, 1888	106	223			329	19	722	320	4,356	134	722
Colorado	Mar. 25, 1889	Feb. 20, 1888	35	70		4	109	24	106	30	(1)	40	(1)
Connecticut:													
State	May 18, 1887	May 18, 1887	59				59	15	787	32	307		
Storrs	do	Apr. 1, 1888	18	11	3	3	35						
Delaware	Apr. 14, 1887	Feb. 21, 1888	14	13	1	5	33	11	224	18	56	7	28
Florida	June 7, 1887	Mar. 16, 1888	115	14	5	5	139	21	637	63	248	83	122
Georgia	Dec. 24, 1888	Feb. 18, 1888	86				86	17	734	34	233		
Hawaii	Mar. 31, 1911	July 1, 1929	26	13			39	8	453	14	87		
Idaho	Jan. 23, 1891	Feb. 26, 1892	13	26	1	4	44	5	108	2	(1)		
Illinois	May 11, 1887	Mar. 21, 1888	53	108	6	2	169	9	308				
Indiana	Jan. 19, 1889	July 1, 1887	109	60	6	4	179	35	1,122	42	179		
Iowa	Mar. 1, 1888	Feb. 17, 1888	85	123	22	7	237	23	1,060	50	544	6	64
Kansas	Mar. 3, 1887	Feb. 8, 1888	48	113			161	10	384	46			
Kentucky	Feb. 20, 1888	Apr. 29, 1888	78	20	2	11	111	22	756	31	135		
Louisiana	July 12, 1888	Apr. 5, 1887	73	39	1		113	15	429	50	348	35	185
Maine	Mar. 16, 1887	Feb. 16, 1888	32	20	2	2	56	11	584	4	40	1	7
Maryland	Mar. 6, 1888	Mar. 9, 1888	15	23	6	18	62	2	75	24	145	7	112
Massachusetts	Apr. 20, 1887	Mar. 2, 1888	67	20			87	18	442	29	148		
Michigan	Apr. 12, 1889	Feb. 26, 1888	79	99	4	9	191	23	1,113	59	372		
Minnesota	Feb. 4, 1889	Jan. 26, 1888	43	113	4	4	164	10	346	47	406	34	123
Mississippi	Jan. 31, 1888	Spring 1888	37	17		10	64	31	423	29	280	77	96
Missouri	June 11, 1889	Jan. 31, 1888	16	96		3	115	13	305				
Montana	Feb. 16, 1893	July 1, 1893	33	31	1	11	76	17	341	6	39	3	124
Nebraska	Mar. 31, 1887	June 14, 1887	39	44	1		84	9	274	30	(1)		
Nevada	Feb. 8, 1889	Dec. 1887	14			1	15	1	35				

New Hampshire	Aug. 4, 1887	Feb. 22, 1888	10	39	1	8	58	8	160	7	42	3	18
New Jersey	Mar. 16, 1887	Mar. 5, 1888	59	60	----------	3	122	21	575	59	542	----------	----------
New Mexico	Feb. 28, 1889	Nov. 14, 1889	17	20	1	1	39	8	236	----------	----------	----------	----------
New York:													
Cornell	Mar. 30, 1887	Apr. 30, 1888	32	138	3	20	193	12	921	396	1,989	----------	----------
State	(2)	----------	67	----------	----------	----------	67	7	292	34	77	4	64
North Carolina	Mar. 7, 1887	Dec. 5, 1889	83	44	----------	10	137	8	431	----------	----------	3	44
North Dakota	Mar. 8, 1890	Oct. 15, 1890	36	22	----------	1	59	13	304	2	12	1	16
Ohio	Mar. 16, 1887	Apr. 2, 1888	145	2	----------	----------	147	19	574	----------	----------	----------	----------
Oklahoma	Oct. 27, 1890	Aug. 14, 1891	38	65	----------	----------	103	20	622	72	537	----------	----------
Oregon	Feb. 25, 1889	July 2, 1888	58	63	----------	6	127	15	450	20	100	26	130
Pennsylvania	June 3, 1887	June 30, 1887	----------	169	----------	----------	169	11	549	39	281	11	120
Puerto Rico	Aug. 16, 1933	Nov. 14, 1935	69	----------	----------	----------	69	8	532	5	31	----------	----------
Rhode Island	Mar. 31, 1887	Nov. 3, 1888	19	9	1	5	34	4	185	12	52	2	12
South Carolina	Dec. 22, 1887	Jan. 1888	61	21	3	1	86	6	354	----------	----------	----------	----------
South Dakota	Mar. 11, 1887	Nov. 17, 1887	19	22	2	1	44	10	298	6	(1)	----------	----------
Tennessee	Mar. 29, 1887	July 24, 1887	53	16	1	8	78	6	125	15	96	17	784
Texas	Apr. 2, 1887	Jan. 25, 1888	177	1	----------	----------	178	15	648	74	746	154	1,054
Utah	Mar. 8, 1888	Nov. 6, 1889	25	40	----------	6	71	4	134	9	148	----------	----------
Vermont	Nov. 1888	Feb. 28, 1888	8	13	4	7	32	11	437	----------	----------	----------	----------
Virginia	Feb. 29, 1888	June 13, 1888	85	13	1	6	105	27	521	----------	----------	----------	----------
Washington	Mar. 9, 1891	May 1, 1891	68	51	3	----------	122	19	278	42	194	----------	----------
West Virginia	Feb. 22, 1889	June 11, 1888	21	42	1	7	71	4	213	14	89	----------	----------
Wisconsin	(3)	July 1, 1887	55	86	4	16	161	7	233	----------	----------	----------	----------
Wyoming	Jan. 10, 1891	Mar. 27, 1891	21	30	----------	----------	51	7	220	12	41	3	313
Total	----------	----------	2,621	2,366	92	211	5,290	681	21,874	1,816	13,149	663	4,201

[1] Total pages unknown.
[2] First made eligible to receive part of the State allotment of Federal funds by legislative act approved May 12, 1894.
[3] Session of 1887.

TABLE 2.—*Income of the experiment stations for the year ended June 30, 1947*

Station	Federal grants [1]			Non-Federal							Grand total
	Hatch, Adams and Purnell [2]	Bankhead-Jones	Total	State appropriations	Special endowments, industrial fellowships, etc.	Fees	Sales	Miscellaneous	Balance from previous year	Total	
Alabama	90,000	$89,423.98	$179,423.98	$341,210.00	[3] $18,153.48		$214,728.07	$5,893.17	[3] $243,191.62	$823,176.34	$1,002,600.32
Alaska	42,500	2,440.15	44,940.15	7,500.00			24,406.21		11,192.42	43,098.63	88,038.78
Arizona	90,000	14,392.26	104,392.26	206,474.01	11,849.57		23,840.92		15,499.64	257,664.14	362,056.40
Arkansas	90,000	69,148.00	159,148.00	138,669.73			125,235.00	5,000.00	21,623.76	290,528.49	449,676.49
California	90,000	88,718.14	178,718.14	2,353,759.03	132,146.24		188,003.64		153,569.98	2,827,478.89	3,006,197.03
Colorado	90,000	24,243.47	114,243.47	156,656.07	37,901.86	$3,037.62	98,905.60		110,603.09	407,104.24	521,347.71
Connecticut:											
State	45,000	12,191.48	57,191.48	202,005.97	18,111.73					220,117.70	277,309.18
Storrs	45,000	12,191.47	57,191.47	146,542.82	20,266.15					166,808.97	224,000.44
Delaware	90,000	5,622.44	95,622.44	54,519.66			78,208.30	17,857.55	59,200.46	209,785.97	305,408.41
Florida	90,000	37,680.70	127,680.70	1,856,657.53			217,071.81	65,832.74	121,420.43	2,260,982.51	2,388,663.21
Georgia	90,000	94,499.88	184,499.88	167,444.80	44,194.89		66,521.13	25,248.99	94,137.47	397,547.28	582,047.16
Hawaii	90,000	9,727.90	99,727.90	275,852.98	8,095.81		25,612.52		1,666.98	311,228.29	410,956.19
Idaho	90,000	15,404.82	105,404.82	51,929.57			56,306.49		24,270.20	132,506.26	237,911.08
Illinois	90,000	93,841.72	183,841.72	667,364.99	162,522.79		242,348.44			1,072,236.22	1,256,077.94
Indiana	90,000	68,142.18	158,142.18	546,517.40	257,607.44	85,500.00	397,618.88	7,552.44	548,092.30	1,842,888.46	2,001,030.64
Iowa	90,000	69,803.53	159,803.53	383,703.99	220,233.75		181,669.85		187,384.29	972,991.88	1,132,795.41
Kansas	90,000	53,614.75	143,614.75	177,401.42			132,613.09	53,898.90	250,609.47	614,522.88	758,137.63
Kentucky	90,000	88,327.80	178,327.80	122,592.11		153,506.56	51,000.00			327,098.67	505,426.47
Louisiana	90,000	61,211.39	151,211.39	483,055.17	33,145.40					516,200.57	667,411.96
Maine	90,000	22,408.10	112,408.10	128,270.93	5,356.20		48,362.86	38,093.88	24,867.21	244,951.08	357,359.18
Maryland	90,000	32,781.37	122,781.37	106,529.00	52,207.50		72,590.15		55,304.07	286,630.72	409,412.09
Massachusetts	90,000	20,231.15	110,231.15	242,005.24	26,907.50				30,036.34	298,949.08	409,180.23
Michigan	90,000	79,697.18	169,697.18	424,763.90			48,245.02			473,008.92	642,706.10
Minnesota	90,000	62,041.49	152,041.49	581,268.09	57,730.95	9,167.16	211,410.23			859,576.43	1,011,617.92
Mississippi	90,000	78,610.71	168,610.71	741,211.87	46,114.65		173,783.97	10,065.36	186,101.05	1,157,276.90	1,325,887.61
Missouri	90,000	83,175.72	173,175.72	137,300.00	37,366.36	93,666.31	103,425.80		143,895.94	515,654.41	688,830.13
Montana	90,000	16,687.31	106,687.31	186,901.70			215,868.37	5,602.83	135,828.19	544,201.09	650,888.40
Nebraska	90,000	41,505.16	131,505.16	210,621.59			227,850.56			438,472.15	569,977.31
Nevada	90,000	2,962.52	92,962.51	2,962.52			27,754.80		9,809.49	40,526.81	133,489.33

New Hampshire	90,000	9,216.35	99,216.35	16,224.46			9,127.70		32,605.44	57,957.60	157,173.95
New Jersey	90,000	33,865.35	123,865.35	514,751.84	228,015.91				9,636.56	752,404.31	876,269.66
New Mexico	90,000	15,725.69	105,725.69	63,500.00			52,680.71		107,242.04	223,422.75	329,148.44
New York:											
Cornell	81,000	92,116.31	173,116.31	1,109,311.36			230,359.18	4,511.35		1,344,181.89	1,517,298.20
State	9,000	10,235.14	19,235.14	554,919.43			21,239.44			576,158.87	595,394.01
North Carolina	90,000	114,926.05	204,926.05	336,210.65			68,232.39	35,806.03		440,249.07	645,175.12
North Dakota	90,000	26,411.59	116,411.59	217,542.85	17,837.65		52,405.69		52,989.87	340,776.06	457,187.65
Ohio	90,000	101,527.46	191,527.46	1,352,088.79			153,639.74		696,317.54	2,202,046.07	2,393,573.53
Oklahoma	90,000	73,409.01	163,409.01	423,434.92	13,203.27		172,618.59		230,285.90	839,542.68	1,002,951.69
Oregon	90,000	24,689.53	114,689.53	368,818.60	48,096.52	165,164.16	145,813.50			727,892.78	842,582.31
Pennsylvania	90,000	146,599.59	236,599.59	306,529.19	122,033.32		127,846.72	85,104.82	46,468.18	687,982.23	924,581.82
Puerto Rico	90,000	57,647.71	147,647.71	342,360.00	9,300.00		34,817.00	77,078.04		463,555.04	611,202.75
Rhode Island	90,000	2,653.11	92,653.11	25,000.00	31,850.00		31,730.62		15,003.08	103,583.70	196,236.81
South Carolina	90,000	64,344.59	154,344.59	240,000.00	25,540.75		400,163.75		148,490.25	814,194.75	968,539.34
South Dakota	90,000	26,082.74	116,082.74	56,500.00	4,398.68		70,177.25		40,052.02	171,127.95	287,210.69
Tennessee	90,000	83,564.08	173,564.08	158,601.50			118,961.00			277,562.50	451,126.58
Texas	90,000	161,288.81	251,288.81	569,105.63	70,365.53		504,146.25	142,651.52	560,470.49	1,846,739.42	2,098,028.23
Utah	90,000	11,336.91	101,336.91	133,896.32	17,826.07		41,084.10	750.00	79,706.18	273,262.67	374,599.58
Vermont	90,000	11,274.80	101,274.80	18,500.00			3,204.21	9,542.02	5,640.12	36,886.35	138,161.15
Virginia	90,000	77,043.23	167,043.23	367,122.00			59,963.00			427,085.00	594,128.23
Washington	90,000	36,025.87	126,025.87	509,672.96	74,245.31		231,711.02			815,629.29	941,655.16
West Virginia	90,000	60,514.12	150,514.12	74,324.70	8,000.00		119,351.29		61,644.88	263,320.87	413,834.99
Wisconsin	90,000	65,188.75	155,188.75	805,906.00	371,281.00		218,100.00			1,395,287.00	1,550,475.75
Wyoming	90,000	7,294.44	97,294.44	104,929.04			94,918.16		42,187.57	242,034.77	339,329.21
Total	4,542,500	2,663,708.00	7,206,208.00	19,770,942.33	2,231,906.28	510,041.81	6,215,673.02	590,489.64	4,557,044.52	33,876,097.60	41,082,305.60

[1] Includes unexpended balances from the previous year as follows:
Hatch—Arkansas, $376.83; Connecticut State, $6.15; Connecticut Storrs, $1,171.78; New York Cornell, $20.65; New York State, $45.86; Ohio, $148.17; Rhode Island, $40.62.
Adams—Arkansas, $2.08; Connecticut Storrs, $100.00; Delaware, $262.99; Indiana, $23.74; New York Cornell, $19.26; North Dakota, $0.05; Ohio, $761.88; Rhode Island, $51.71.
Purnell—Arkansas, $108.37; Connecticut State, $449.09; Connecticut Storrs, $1,880.44; Delaware, $1,454.42; Indiana, $3,792.09; Maryland, $24.47; New York Cornell, $394.49; New York State, $12.80; Ohio, $269.35; Rhode Island, $51.84.
Bankhead-Jones—Arkansas, $12.02; Connecticut State, $694.17; Connecticut Storrs, $1,934.19; Hawaii, $0.02; Indiana, $1,139.70; Mississippi, $0.01; Ohio, $4.48; Utah, $659.17.

[2] Hatch, $15,000 for each State, Alaska, Hawaii, and Puerto Rico. Adams, $15,000 for each State, Hawaii, and Puerto Rico; $7,500 for Alaska. Purnell, $60,000 for each State, Hawaii, and Puerto Rico; $20,000 for Alaska.

[3] Does not include TVA.

TABLE 3.—*Expenditures and appropriations under the Hatch Act (Mar. 2, 1887)[1] for the year ended June 30, 1947*

Station	Expenditures												Unexpended	Appropriations
	Personal Services	Travel	Transportation of things	Communication service	Rents and utility services	Printing and binding	Other contractual services	Supplies and materials	Equipment	Lands and structures (contractual)	Contributions to retirement	Total expenditures		
Alabama	$12,486.14	$154.01	$15.67	$292.57		$578.51	$32.95	$977.55	$462.60			$15,000.00		$15,000
Alaska	11,569.72	597.30		25.21	$124.83		28.75	2,047.44	606.75			15,000.00		15,000
Arizona	14,170.92	630.33	4.21	68.15		22.58	9.08	94.73				15,000.00		15,000
Arkansas	11,310.72	813.94	3.22	198.84		1,259.03	47.88	922.50	251.48		$192.39	15,000.00		15,000
California	15,000.00											15,000.00		15,000
Colorado	13,103.70	1,034.24		32.72		8.50	87.64	528.93			204.27	15,000.00		15,000
Connecticut:														
State	6,630.00						470.74	376.22	12.49			7,489.45	$10.55	7,500
Storrs	3,191.92	587.65	2.81	33.45		158.21		1,208.31	1,700.59			6,882.94	617.06	7,500
Delaware	11,185.68	375.07	16.87	764.03	18.31	1,016.79	131.47	945.80	545.98			15,000.00		15,000
Florida	15,000.00											15,000.00		15,000
Georgia	10,887.62	394.90		2.64		626.96	109.21	2,271.90	706.77			15,000.00		15,000
Hawaii	12,486.63					1,882.00		239.99	391.38			15,000.00		15,000
Idaho	11,160.22	1,955.72	31.69	171.93		962.02	13.00	705.42				15,000.00		15,000
Illinois	14,426.43										573.57	15,000.00		15,000
Indiana	15,000.00											15,000.00		15,000
Iowa	15,000.00											15,000.00		15,000
Kansas	14,218.33	353.14		63.14	12.00		7.47	223.40	122.52			15,000.00		15,000
Kentucky	14,204.93	164.83				630.24						15,000.00		15,000
Louisiana	13,597.16	127.44	44.23	7.62		231.32	94.61	247.62	650.00			15,000.00		15,000
Maine	11,094.24	1,508.01	24.75	311.92	946.18	366.09	90.55	471.82	186.44			15,000.00		15,000
Maryland	12,305.50	647.70	.65				25.47	1,931.95	88.73			15,000.00		15,000
Massachusetts	10,474.62	639.40					1,187.50	846.69	1,644.19	$207.60		15,000.00		15,000
Michigan	15,000.00											15,000.00		15,000
Minnesota	12,668.79	292.97		59.50		43.75	120.11	866.63	546.86		401.39	15,000.00		15,000
Mississippi	9,971.33	307.34	20.92	451.78	80.96	483.00	115.54	1,490.66	2,078.47			15,000.00		15,000
Missouri	14,644.74										355.26	15,000.00		15,000
Montana	11,940.53	45.25	25.13	146.80	28.17	1,236.09	220.17	777.55	580.31			15,000.00		15,000
Nebraska	15,000.00											15,000.00		15,000
Nevada	11,618.97	161.35	20.07	383.18	191.98	599.15	97.45	1,491.54		27.80	408.51	15,000.00		15,000

New Hampshire	11,503.50	674.08	311.93	229.88	700.00	219.99	35.12	803.17	522.33			15,000.00		15,000
New Jersey	14,251.21	346.84			20.00		27.00	126.07	228.88			15,000.00		15,000
New Mexico	13,749.26	402.70	8.05	9.24	173.39	331.00	43.11	156.55	126.70			15,000.00		15,000
New York:														
Cornell	11,635.78	22.05			18.45		266.54	1,495.70	57.00			13,495.52	4.48	13,500
State	862.50								637.50			1,500.00		1,500
North Carolina	12,971.85	258.15	57.81	38.87		646.25	205.11	813.96	8.00			15,000.00		15,000
North Dakota	13,696.56		1.05	1.04		400.92	6.20	524.87	43.29		326.07	15,000.00		15,000
Ohio	12,676.05	1,230.78						752.71	340.46			15,000.00		15,000
Oklahoma	6,289.66	1,289.07	200.06	14.75		282.52	1,514.31	4,439.17	970.46			15,000.00		15,000
Oregon	12,147.87	954.87	21.53	19.67	7.48	1,489.80		199.14	159.64			15,000.00		15,000
Pennsylvania	12,481.22	420.91	3.68			2,016.20		77.99				15,000.00		15,000
Puerto Rico	9,983.73	670.34		111.75	139.38			3,436.24	658.56			15,000.00		15,000
Rhode Island	9,249.26	320.45	43.45	310.39		794.04	547.20	2,435.39	1,166.68			14,866.86	133.14	15,000
South Carolina	11,663.40	24.25	33.63	433.39		198.39	161.39	1,607.48	878.07			15,000.00		15,000
South Dakota	11,421.45	1,124.66	4.80	253.58	6.00	1,172.19	292.96	268.20	456.16			15,000.00		15,000
Tennessee	12,949.88		81.13	229.84	14.35		116.57	1,076.78	531.45			15,000.00		15,000
Texas	10,420.00	2,991.83		96.19		228.86	48.50	125.67	1,088.95			15,000.00		15,000
Utah	13,850.87		3.04				5.60	1,125.04	15.45			15,000.00		15,000
Vermont	7,271.49	360.83	4.30	816.89	1,678.51	1,675.46	707.55	2,280.39	122.90		81.68	15,000.00		15,000
Virginia	14,183.57			18.33			120.71	371.60	305.79			15,000.00		15,000
Washington	13,607.64	330.38	10.43	11.42		26.49	344.02	283.02	8.10		378.50	15,000.00		15,000
West Virginia	12,160.00	293.98	2.89		229.59	451.22	41.14	1,816.18	5.00			15,000.00		15,000
Wisconsin	13,581.47	334.37				10.00		1,074.16				15,000.00		15,000
Wyoming	13,104.85	280.10	7.02	21.23		921.60		563.80	101.40			15,000.00		15,000
Total	635,061.91	23,121.23	1,005.02	5,629.94	4,389.58	20,969.17	7,372.62	44,519.93	19,008.33	235.40	2,921.64	764,234.77	765.23	765,000

[1] Extended to Hawaii by act of May 16, 1928; to Alaska by act of Feb. 23, 1929; and to Puerto Rico by act of Mar. 4, 1931.

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TABLE 4.—*Expenditures and appropriations under the Adams Act (Mar. 16, 1906)[1] for the year ended June 30, 1947*

Station	Expenditures											Unexpended	Appropriations
	Personal services	Travel	Transportation of things	Communication service	Rents and utility services	Other contractual services	Supplies and materials	Equipment	Lands and structures (contractual)	Contributions to retirement	Total expenditures		
Alabama	$12,798.62	$159.00	$34.11	$0.76	$469.17	$47.24	$1,066.15	$424.95			$15,000.00		$15,000
Alaska	7,052.00	127.60	92.90				140.00	87.50			7,500.00		7,500
Arizona	12,346.24	1,505.70	42.41	35.44		100.55	740.11	229.55			15,000.00		15,000
Arkansas	13,496.93	94.01	.54		170.00	35.05	475.20	222.41		$505.03	14,999.17	$0.83	15,000
California	15,000.00										15,000.00		15,000
Colorado	10,899.83	667.87	26.42	21.05	364.58	757.02	1,064.49	1,039.53		159.21	15,000.00		15,000
Connecticut:													
State	7,500.00										7,500.00		7,500
Storrs	7,500.00										7,500.00		7,500
Delaware	10,494.36	420.56	4.35	1.30	73.24	573.52	524.05	2,908.62			15,000.00		15,000
Florida	15,000.00										15,000.00		15,000
Georgia	12,314.05	150.07	12.24	2.31		533.36	1,445.83	542.14			15,000.00		15,000
Hawaii	15,000.00										15,000.00		15,000
Idaho	12,601.33	291.27	16.13	2.67	14.60	104.36	902.24	428.93	$638.47		15,000.00		15,000
Illinois	14,336.25						106.00			557.75	15,000.00		15,000
Indiana	13,636.34			11.50			1,325.46	26.70			15,000.00		15,000
Iowa	15,000.00										15,000.00		15,000
Kansas	13,641.14					25.31	1,041.23	269.17			14,976.85	23.15	15,000
Kentucky	14,998.20						1.80				15,000.00		15,000
Louisiana	13,000.66	356.38	20.04	1.96		623.97	397.26	599.73			15,000.00		15,000
Maine	14,647.19	53.55				30.36	266.40	2.50			15,000.00		15,000
Maryland	12,471.06	915.68	2.38			75.00	1,090.07	445.80			14,999.99	.01	15,000
Massachusetts	15,000.00										15,000.00		15,000
Michigan	14,921.80	54.07					24.13				15,000.00		15,000
Minnesota	13,405.59	15.00	.48				732.63	472.19		374.11	15,000.00		15,000
Mississippi	12,493.55	419.91	66.88	33.24	288.83	112.25	1,074.07	511.27			15,000.00		15,000
Missouri	9,692.26	60.00	119.04	18.00	50.39	27.06	3,870.61	1,000.65		160.99	15,000.00		15,000
Montana	12,726.60	300.65	53.20	6.06		99.41	879.55	934.53			15,000.00		15,000
Nebraska	15,000.00										15,000.00		15,000
Nevada	12,521.58	187.50		5.69			1,635.81	116.66		532.76	15,000.00		15,000

New Hampshire	13,757.86	168.94	14.74	10.17	----------	417.06	398.82	232.41	----------	----------	15,000.00	----------	15,000
New Jersey	13,070.00	----------	5.84	----------	----------	91.55	1,610.65	221.96	----------	----------	15,000.00	----------	15,000
New Mexico	13,332.76	31.03	21.44	----------	205.61	53.90	697.16	658.10	----------	----------	15,000.00	----------	15,000
New York:													
Cornell	11,176.08	12.55	----------	----------	26.88	232.35	1,837.24	191.50	----------	----------	13,476.60	23.40	13,500
State	769.80	----------	----------	----------	----------	----------	325.01	405.19	----------	----------	1,500.00	----------	1,500
North Carolina	13,464.72	140.71	29.57	.62	----------	94.83	577.41	692.14	----------	----------	15,000.00	----------	15,000
North Dakota	13,119.61	20.96	1.85	27.69	----------	----------	379.04	1,117.35	----------	333.47	14,999.97	.03	15,000
Ohio	13,220.65	1.85	20.38	----------	----------	----------	1,351.16	405.96	----------	----------	15,000.00	----------	15,000
Oklahoma	11,848.79	106.21	2.73	9.19	----------	148.04	1,527.92	1,357.12	----------	----------	15,000.00	----------	15,000
Oregon	13,953.63	223.48	1.39	4.43	.62	38.40	635.30	142.75	----------	----------	15,000.00	----------	15,000
Pennsylvania	14,855.46	----------	----------	----------	----------	----------	----------	144.54	----------	----------	15,000.00	----------	15,000
Puerto Rico	12,077.58	233.75	----------	----------	9.00	685.15	1,130.70	863.82	----------	----------	15,000.00	----------	15,000
Rhode Island	13,998.47	35.89	1.30	----------	----------	10.00	581.85	347.80	----------	----------	14,975.31	24.69	15,000
South Carolina	12,661.49	134.73	4.62	82.94	45.48	366.62	868.45	835.67	----------	----------	15,000.00	----------	15,000
South Dakota	14,044.80	181.20	9.97	.79	----------	23.05	725.19	15.00	----------	----------	15,000.00	----------	15,000
Tennessee	13,807.06	92.54	35.15	----------	18.99	164.56	735.25	146.45	----------	----------	15,000.00	----------	15,000
Texas	14,765.84	----------	43.25	7.84	----------	24.61	28.46	130.00	----------	----------	15,000.00	----------	15,000
Utah	11,718.99	233.98	89.34	1.00	----------	15.50	1,377.85	1,563.34	----------	----------	15,000.00	----------	15,000
Vermont	11,948.94	164.35	66.05	6.55	24.00	189.32	1,360.76	799.03	----------	441.00	15,000.00	----------	15,000
Virginia	12,613.19	280.10	----------	11.10	360.20	113.45	1,514.28	46.68	61.00	----------	15,000.00	----------	15,000
Washington	11,999.33	250.58	----------	15.10	----------	106.46	2,213.32	191.21	----------	224.00	15,000.00	----------	15,000
West Virginia	13,950.00	46.67	9.96	----------	----------	11.05	760.56	221.76	----------	----------	15,000.00	----------	15,000
Wisconsin	12,850.02	----------	264.96	----------	----------	----------	1,885.02	----------	----------	----------	15,000.00	----------	15,000
Wyoming	11,997.15	300.69	21.24	----------	----------	69.62	1,808.74	802.56	----------	----------	15,000.00	----------	15,000
Total	670,497.80	8,439.03	1,134.90	317.40	2,121.59	5,999.98	43,133.23	21,796.17	699.47	3,288.32	757,427.89	72.11	757,500

[1] Extended to Hawaii by act of May 16, 1928; to Puerto Rico by act of Mar. 4, 1931; and to Alaska by act of June 30, 1936.

TABLE 5.—*Expenditures and appropriations under the Purnell Act (Feb. 24, 1925)[1] for the year ended June 30, 1947*

Station	Expenditures												Unexpended	Appropriation
	Personal services	Travel	Transportation of things	Communication service	Rents and utility services	Printing and binding	Other contractual services	Supplies and materials	Equipment	Lands and structures (contractual)	Contributions to retirement	Total expenditures		
Alabama	$46,713.84	$606.92	$116.46	$154.61	$1,648.47	$86.24	$406.05	$4,184.68	$6,000.14	$82.59		$60,000.00		$60,000
Alaska	19,338.40	97.60	87.50					472.20	4.30			20,000.00		20,000
Arizona	46,106.80	2,281.23	342.37	87.13		63.44	143.22	7,565.20	3,410.61			60,000.00		60,000
Arkansas	43,872.32	174.58		11.00	66.25	804.92	666.71	4,844.46	6,554.83		$1,042.24	58,637.31	$1,362.69	60,000
California	60,000.00											60,000.00		60,000
Colorado	43,973.50	2,202.17	21.70	34.39	764.74	324.38	1,593.39	2,546.47	7,321.66		1,217.60	60,000.00		60,000
Connecticut:														
State	27,030.71	82.84	46.87			71.46	482.17	1,888.43	397.52			30,000.00		30,000
Storrs	26,064.09	699.32	2.63	30.57			239.15	1,384.55	206.29			28,626.60	1,373.40	30,000
Delaware	43,758.41	3,317.67	15.38	6.39	152.45	660.02	768.99	8,296.75	3,023.94			60,000.00		60,000
Florida	59,579.40			1.05				42.55	377.00			60,000.00		60,000
Georgia	46,912.22	1,401.31	59.49	.31		2,413.13	483.53	6,944.73	1,785.28			60,000.00		60,000
Hawaii	49,753.75							4,368.95	3,244.99			57,367.69	2,632.31	60,000
Idaho	51,356.79	1,645.80	161.77	112.98			584.31	5,362.48	760.44	15.43		60,000.00		60,000
Illinois	51,138.81	1,155.65	8.15				2,123.88	566.59	3,855.31		1,151.61	60,000.00		60,000
Indiana	53,330.05	1,460.23	32.56	80.10	20.25	91.95	226.33	2,229.25	2,529.28			60,000.00		60,000
Iowa	60,000.00											60,000.00		60,000
Kansas	56,627.52	266.32			4.49	35.00	484.94	2,321.23		260.50		60,000.00		60,000
Kentucky	53,179.17	2,639.09	5.74	27.84		3,373.06	218.92	452.68	103.50			60,000.00		60,000
Louisiana	46,693.22	2,321.84	74.22	57.70	15.49	1,075.08	1,793.87	4,301.10	3,667.48			60,000.00		60,000
Maine	47,353.40	1,435.49	2.08	133.49	897.60	91.40	598.02	7,395.07	2,093.45			60,000.00		60,000
Maryland	45,602.08	1,377.76	34.43	57.00	44.92	706.98	1,405.16	7,939.94	2,831.73			60,000.00		60,000
Massachusetts	52,914.87	1,233.07					310.51	3,241.17	2,300.38			60,000.00		60,000
Michigan	57,103.08	287.58			400.00	401.70	97.25	943.27	767.12			60,000.00		60,000
Minnesota	51,067.89	2,655.47	137.20	283.48		1,043.83	508.25	3,237.13	1,321.95		744.80	60,000.00		60,000
Mississippi	41,510.37	2,619.20	114.83	584.30	749.11	1,110.96	238.50	6,967.78	6,090.10	14.85		60,000.00		60,000
Missouri	46,041.38	544.16	239.69	20.87	148.54	634.64	438.01	9,244.13	1,907.23	62.88	718.47	60,000.00		60,000
Montana	50,095.49	1,506.45	42.75	103.98	890.16	523.26	574.05	3,433.06	2,830.80			60,000.00		60,000
Nebraska	51,199.47	1,725.79	106.53	31.36		111.14	1,381.34	3,396.41	2,047.96			60,000.00		60,000
Nevada	44,506.95	906.52	237.15	517.83	348.24	344.22	278.36	10,707.67	731.53	622.00	799.53	60,000.00		60,000

New Hampshire	52,934.79	1,011.68	208.14	29.83	204.07	200.72	181.37	2,227.65	2,814.33	187.42	----------	60,000.00	----------	60,000
New Jersey	49,465.73	1,235.05	24.17	20.00	118.00	----------	1,285.20	3,186.71	4,290.17	374.97	----------	60,000.00	----------	60,000
New Mexico	47,634.84	1,683.44	53.35	112.46	1,655.79	764.86	623.08	5,771.15	1,685.91	----------	----------	59,984.88	15.12	60,000
New York:														
Cornell	43,654.34	1,968.59	45.25	23.97	1,118.30	17.75	1,667.28	1,922.75	2,223.85	----------	----------	52,642.08	1,357.92	54.000
State	5,220.95	----------	----------	----------	10.00	----------	97.56	295.37	276.92	----------	----------	5,900.80	99.20	6,000
North Carolina	49,566.13	3,801.37	7.56	305.53	14.74	268.61	774.60	3,519.58	1,741.88	----------	----------	60,000.00	----------	60,000
North Dakota	53,862.64	1,104.62	1.60	48.02	9.38	308.22	119.31	2,568.56	761.49	----------	1,216.02	59,999.86	.14	60,000
Ohio	54,894.80	802.58	34.53	----------	----------	----------	17.48	2,061.65	2,188.96	----------	----------	60,000.00	----------	60,000
Oklahoma	43,844.26	1,024.54	91.24	----------	83.26	74.59	2,790.55	7,793.28	3,407.38	890.90	----------	60,000.00	----------	60,000
Oregon	50,768.59	2,766.69	198.42	520.14	49.76	240.10	2,433.98	1,991.65	1,030.67	----------	----------	60,000.00	----------	60,000
Pennsylvania	52,332.49	2,658.62	.48	70.00	----------	1,058.00	169.66	2,722.38	988.37	----------	----------	60,000.00	----------	60,000
Puerto Rico	46,152.91	2,227.87	30.33	----------	30.00	450.00	188.32	6,267.00	4,653.57	----------	----------	60,000.00	----------	60,000
Rhode Island	52,844.92	529.69	16.64	----------	----------	216.50	27.00	5,655.96	569.90	----------	----------	59,860.61	139.39	60,000
South Carolina	50,064.01	977.98	41.18	324.81	1,438.95	580.81	502.82	3,463.62	2,605.82	----------	----------	60,000.00	----------	60,000
South Dakota	47,842.94	3,006.28	508.75	46.30	8.00	1,507.57	268.34	4,179.45	2,632.37	----------	----------	60,000.00	----------	60,000
Tennessee	52,753.01	869.04	111.80	15.53	222.00	10.00	60.26	3,142.21	2,816.15	----------	----------	60,000.00	----------	60,000
Texas	50,166.16	1,188.18	102.34	387.65	12.17	24.63	720.77	3,501.38	3,896.72	----------	----------	60,000.00	----------	60,000
Utah	51,331.46	2,991.54	47.92	10.00	40.50	3.75	542.46	2,740.88	1,909.55	381.94	----------	60,000.00	----------	60,000
Vermont	48,491.25	1,711.73	38.22	166.56	109.93	1,269.63	423.84	3,296.51	2,639.32	468.26	1,384.75	60,000.00	----------	60,000
Virginia	49,143.63	2,037.18	28.48	41.79	1,458.39	----------	1,795.79	3,375.63	2,084.21	34.90	----------	60,000.00	----------	60,000
Washington	53,069.55	923.67	----------	258.04	----------	67.28	371.39	2,761.35	2,162.72	----------	386.00	60,000.00	----------	60,000
West Virginia	55,146.49	456.20	2.81	----------	724.80	518.04	45.30	2,814.86	291.50	----------	----------	60,000.00	----------	60,000
Wisconsin	55,631.09	539.88	107.35	1.40	3.73	----------	104.71	3,529.16	82.68	----------	----------	60,000.00	----------	60,000
Wyoming	50,176.96	2,722.28	305.52	126.04	31.00	822.24	307.66	3,373.85	2,134.45	----------	----------	60,000.00	----------	60,000
Total	2,539,817.92	71,882.76	3,895.58	4,844.45	14,093.48	22,370.11	31,563.64	196,440.52	116,053.71	3,396.64	8,661.02	3,013,019.83	6,980.17	3,020,000

[1] Extended to Hawaii by act of May 16, 1928; to Alaska by act of Feb. 23, 1929; and to Puerto Rico by act of Mar. 4, 1931.

TABLE 6.—*Expenditures and appropriations under the Bankhead-Jones Act (June 29, 1935) for the year ended June 30, 1947*

Station	Expenditures												Unexpended	Appropriation
	Personal services	Travel	Transportation of things	Communication service	Rents and utility services	Printing and binding	Other contractual services	Supplies and materials	Equipment	Lands and structures (contractual)	Contributions to retirement	Total expenditures		
Alabama	$67,800.28	$1,089.59	$436.57	$131.35	$1,639.65	$893.64	$1,621.65	$11,827.78	$3,983.47			$89,423.98		$89,423.98
Alaska	2,165.66	42.70	22.54					209.25				2,440.15		2,440.15
Arizona	11,281.30	1,471.42	156.82	146.27		1.25	107.03	906.73	321.44			14,392.26		14,392.26
Arkansas	47,070.36	1,378.36	29.58		316.45	87.80	767.47	2,946.67	3,973.16	$11,598.31	$942.56	69,110.72	$37.28	69,148.00
California	88,655.88	62.26										88,718.14		88,718.14
Colorado	18,314.43	553.24	9.96	29.02	434.21	442.00	465.01	770.02	2,857.37		368.21	24,243.47		24,243.47
Connecticut:														
State	10,117.50	52.60	26.59			442.36	41.21	952.40	558.82			12,191.48		12,191.48
Storrs	6,394.54							2,722.10	2,652.26			11,768.90	422.57	12,191.47
Delaware	3,922.55						24.50	1,570.39	105.00			5,622.44		5,622.44
Florida	28,546.03	313.08	193.18	.25	4.80		112.60	6,793.97	1,716.79			37,680.70		37,680.70
Georgia	57,509.88	1,161.21	23.91	3.72		884.17	1,758.42	25,963.53	6,991.28	203.76		94,499.88		94,499.88
Hawaii	7,593.23							556.17	232.65			8,382.05	1,345.85	9,727.90
Idaho	12,707.14	361.17	1.34	4.30	240.00	35.25	15.05	2,040.57				15,404.82		15,404.82
Illinois	79,031.38	1,822.10	29.90	38.77			4,662.27	4,144.15	1,373.89		2,739.26	93,841.72		93,841.72
Indiana	58,228.32	996.22	65.51	44.44	428.00		263.66	6,352.53	1,763.50			68,142.18		68,142.18
Iowa	69,803.53											69,803.53		69,803.53
Kansas	48,911.15	342.56			22.50	160.70	640.96	3,258.58		278.30		53,614.75		53,614.75
Kentucky	80,920.52	1,396.76	27.21	5.75		2,712.63	68.23	2,882.45	314.25			88,327.80		88,327.80
Louisiana	47,568.12	2,685.44	62.58	33.90		353.02	1,264.56	5,544.07	3,699.70			61,211.39		61,211.39
Maine	18,655.61	1,160.58		17.19	133.90	43.23	310.82	1,291.46	795.31			22,408.10		22,408.10
Maryland	23,952.56	553.58	11.79		114.62	95.00	706.40	6,078.96	1,268.45			32,781.36	.01	32,781.37
Massachusetts	20,168.15							15.00	48.00			20,231.15		20,231.15
Michigan	73,112.33	1,505.13	3.68	.48	22.00	6.70	641.82	3,509.85	895.19			79,697.18		79,697.18
Minnesota	46,748.40	2,460.90	585.65	133.00	67.70	38.17	1,043.84	7,155.15	3,163.80		644.87	62,041.48	.01	62,041.49
Mississippi	62,204.83	1,538.85	340.34	260.06	1,318.75	275.77	436.75	8,175.19	3,455.78	604.39		78,610.71		78,610.71
Missouri	56,054.70	1,010.00	194.29	249.94	790.23	991.29	952.59	18,452.13	3,609.39	118.30	752.86	83,175.72		83,175.72
Montana	13,714.65	59.91		84.74	93.24		84.89	2,576.93	72.95			16,687.31		16,687.31
Nebraska	32,068.84	994.30	39.33	4.37	100.00	328.94	635.40	6,204.12	1,129.86			41,505.16		41,505.16
Nevada	2,773.96	118.56			5.00						65.00	2,962.52		2,962.52

New Hampshire	7,380.38	534.48	34.98	13.67	148.66	3.45	42.78	766.17	116.36	175.42		9,216.35		9,216.35
New Jersey	26,835.08	872.85			120.00		62.40	5,069.43	905.59			33,865.35		33,865.35
New Mexico	12,344.61	19.82			166.73		375.87	2,635.16	183.50			15,725.69		15,725.69
New York:														
Cornell	65,986.38	2,541.97	265.69		2,255.35	73.20	1,647.54	14,342.87	5,002.33			92,115.33	.98	92,116.31
State	7,044.87						94.05	955.86	2,086.81			10,181.59	53.55	10,235.14
North Carolina	92,829.10	4,236.22	304.70	440.16	200.78	202.73	2,297.74	9,366.83	5,047.79			114,926.05		114,926.05
North Dakota	23,715.93	449.67	59.24	6.89	4.00	177.65	150.00	1,002.15	226.63		619.43	26,411.59		26,411.59
Ohio	89,952.04	558.98	279.79			93.56	80.07	6,399.18	4,163.84			101,527.46		101,527.46
Oklahoma	41,822.26	709.79	108.23	13.14	29.52	59.96	3,532.73	17,053.37	9,255.69	824.32		73,409.01		73,409.01
Oregon	21,078.52	1,013.17	3.99	26.79		1.51	352.89	1,845.97	366.69			24,689.53		24,689.53
Pennsylvania	120,007.45	5,936.01	37.39		10.00		520.10	10,553.22	9,535.42			146,599.59		146,599.59
Puerto Rico	35,808.64	478.37			1,036.22	358.34	390.55	16,968.22	2,607.37			57,647.71		57,647.71
Rhode Island	2,564.98							55.49	32.64			2,653.11		2,653.11
South Carolina	52,068.73	235.38	175.62	125.75	368.04	121.49	1,252.72	5,499.48	4,497.38			64,344.59		64,344.59
South Dakota	18,304.77	1,245.21	32.74	63.48	9.00	369.88	574.81	4,494.84	988.01			26,082.74		26,082.74
Tennessee	69,298.97	974.76	106.03	26.66	136.15	13.87	1,301.71	9,791.24	1,914.69			83,564.08		83,564.08
Texas	133,132.33	2,977.92	73.22	186.24	56.00	58.98	1,696.28	14,602.58	8,194.78	310.48		161,288.81		161,288.81
Utah	9,909.00	942.28					66.28	221.61	197.74			11,336.91		11,336.91
Vermont	8,920.48	153.12	6.32	24.51	123.02		227.75	536.95	998.45		284.20	11,274.80		11,274.80
Virginia	73,366.22	423.31		26.65	27.24	433.00	355.64	1,704.12	707.05			77,043.23		77,043.23
Washington	26,432.92	1,559.32		9.73			187.31	5,262.80	2,275.79		298.00	36,025.87		36,025.87
West Virginia	52,323.96	1,681.27	36.34		731.36	479.21	222.40	3,698.89	1,340.69			60,514.12		60,514.12
Wisconsin	58,716.12	336.42	259.03				56.31	5,820.87				65,188.75		65,188.75
Wyoming	5,997.40	249.58	1.05	43.60		12.00	38.50	342.65	609.66			7,294.44		7,294.44
Total	2,151,836.97	51,260.42	4,045.13	2,194.82	11,153.12	10,250.75	32,151.56	271,890.10	106,237.21	14,113.28	6,714.39	2,661,847.75	1,860.25	2,663,708.00

TABLE 7.—*Expenditures from non-Federal funds for the year ended June 30, 1947*

Station	Personal services	Travel	Transportation of things	Communication service	Rents and utility services	Printing and binding	Other contractual services	Supplies and materials	Equipment	Lands and structures (contractual)	Contributions to retirement	Total	Unexpended balances
Alabama	$279,198.50	$16,777.90	$4,512.93	$2,479.02	$7,968.35	$2,407.98	$75,748.59	$122,569.01	$38,520.63	$39,892.64	----------	$590,075.55	$233,100.79
Alaska	15,090.01	769.84	3,852.78	324.13	1,106.66	667.05	2,207.00	13,485.84	4,602.41	949.89	----------	43,055.61	43.02
Arizona	163,959.04	7,312.47	520.53	1,342.82	4,882.24	65.30	6,852.42	18,111.56	44,869.76	----------	----------	247,916.14	9,748.00
Arkansas	137,725.46	10,466.62	1,217.56	1,154.79	6,036.33	13.70	3,802.80	63,036.75	33,307.47	7,031.59	$2,085.10	265,878.17	24,650.32
California	2,020,832.01	87,249.11	7,350.87	21,630.33	22,797.18	33,862.95	88,334.86	238,604.61	97,194.49	----------	----------	2,617,856.41	209,622.48
Colorado	173,014.76	9,371.93	1,196.59	2,345.25	10,464.37	1,578.97	8,858.43	76,030.47	22,595.59	6,182.00	2,691.53	314,329.89	92,774.35
Connecticut:													
State	174,359.30	1,221.70	98.87	1,624.96	4,999.80	253.16	2,986.40	17,635.56	15,541.65	----------	----------	218,721.40	1,396.30
Storrs	81,725.67	1,106.03	225.42	163.80	----------	----------	1,044.22	12,331.91	6,102.57	8,790.00	----------	111,489.62	55,319.35
Delaware	61,381.53	2,747.87	462.18	859.13	3,226.79	2,086.58	11,952.26	57,915.01	8,914.69	25,888.38	----------	175,434.42	34,351.55
Florida	846,848.37	41,897.23	6,634.87	7,922.87	17,162.79	64,709.22	----------	244,741.24	105,165.17	235,986.35	----------	1,571,068.11	689,914.40
Georgia	155,455.38	6,045.21	1,772.75	1,513.91	6,307.50	8,732.65	12,419.20	55,205.19	26,916.23	6,497.27	----------	280,865.29	116,681.99
Hawaii	231,064.15	3,127.93	845.80	1,783.65	6,116.54	207.18	13,313.03	41,347.79	12,520.45	----------	----------	310,326.52	901.77
Idaho	71,530.36	3,255.30	750.00	1,000.00	650.00	750.00	861.63	31,504.00	16,953.93	5,251.04	----------	132,506.26	----------
Illinois	687,527.67	45,500.00	----------	17,000.00	----------	35,000.00	----------	245,757.81	41,450.74	----------	----------	1,072,236.22	----------
Indiana	595,534.82	22,261.82	8,212.37	9,950.70	14,457.32	9,684.23	41,133.68	334,311.64	119,077.48	89,753.61	----------	1,244,377.67	598,510.79
Iowa	440,034.62	28,821.56	1,999.38	3,578.90	----------	15,787.75	----------	199,844.56	62,679.41	10,798.45	----------	763,544.63	209,447.25
Kansas	220,683.92	7,207.66	2,209.14	1,843.22	6,846.87	862.12	12,159.60	64,396.14	54,840.40	53,767.08	----------	424,816.15	189,706.73
Kentucky	223,083.20	10,966.29	830.07	3,750.26	824.91	3,525.50	17,810.82	51,597.07	14,710.55	----------	----------	327,098.67	----------
Louisiana	342,673.24	24,770.01	2,240.61	3,635.39	5,159.92	3,244.62	15,678.32	77,725.70	37,846.69	3,226.07	----------	516,200.57	----------
Maine	141,170.92	15,842.81	846.21	1,299.02	4,947.73	4,732.82	7,329.53	37,419.28	10,817.41	----------	----------	224,405.73	20,545.35
Maryland	109,219.37	2,780.24	874.44	1,255.16	1,391.83	830.62	10,050.97	56,436.28	21,636.55	7,606.47	----------	212,081.93	74,548.79
Massachusetts	218,083.89	3,969.10	302.68	2,167.87	1,768.46	2,552.82	1,330.03	25,928.92	7,251.62	4,887.42	----------	268,242.81	30,706.27
Michigan	363,382.41	18,773.94	966.24	1,133.54	2,016.71	14,045.81	6,445.81	45,908.28	20,327.98	8.20	----------	473,008.92	----------
Minnesota	568,332.64	14,203.99	5,060.12	5,629.51	15,467.26	4,297.34	47,218.01	140,060.00	48,147.93	11,159.63	----------	859,576.43	----------
Mississippi	343,423.77	16,067.37	5,369.34	2,937.11	9,893.52	5,958.23	40,422.33	81,687.74	60,080.56	151,711.26	----------	717,551.23	439,725.67
Missouri	154,140.39	9,218.24	2,303.34	1,854.04	8,671.90	9,266.27	13,794.38	79,779.29	23,120.54	450.31	----------	302,598.70	213,055.71
Montana	198,517.69	9,729.39	2,119.12	2,499.03	13,725.83	3,598.68	12,902.08	94,904.72	59,839.46	7,679.20	3,257.02	408,772.22	135,428.87
Nebraska	91,860.97	19,316.29	10,724.23	4,395.36	9,352.70	1,614.43	9,100.00	212,292.39	78,109.29	1,706.49	----------	438,472.15	----------
Nevada	6,820.43	1,256.77	14.73	534.95	1,502.15	11.76	1,808.06	7,824.73	5,676.32	7,320.75	68.15	32,838.80	7,688.01

New Hampshire	20,422.00	639.76	26.84	426.09		791.25	73.07	1,605.14	444.11			24,428.26	33,529.34
New Jersey	520,266.73	16,891.86	543.48	24.87	26,296.84	6,865.85	33,312.66	115,034.54	25,667.73		190.86	745,095.42	7,308.89
New Mexico	67,726.03	2,742.91	1,077.04	348.25	4,466.02	2,145.24	7,933.16	18,595.50	7,864.75	17,724.71		130,623.61	92,799.14
New York:													
Cornell	954,808.20	22,637.56	2,920.58	9,383.74	59,825.93	7,772.12	18,829.80	186,862.84	79,281.20	1,859.92		1,344,181.89	
State	457,652.71	11,010.46	1,269.32	3,977.64	10,090.85	7,358.40	8,991.05	46,098.80	29,709.64			576,158.87	
North Carolina	294,172.60	13,320.27	1,036.31	3,709.74	5,717.59	3,537.66	16,135.91	57,817.41	27,958.53	16,843.05		440,249.07	
North Dakota	137,035.96	5,346.32	1,299.14	1,455.99	1,638.46	4,884.88	27,519.63	40,648.69	28,884.22	44,022.30	1,813.05	294,548.64	46,227.42
Ohio	464,218.40	7,329.47	3,711.66	2,751.23			11,462.30	162,953.75	41,460.27	5,621.24		699,508.32	1,502,537.75
Oklahoma	338,859.02	14,701.67	5,003.61	2,517.66	13,651.90	4,717.72	37,378.59	160,974.13	63,613.89	61,279.19		702,697.38	136,845.30
Oregon	489,051.94	22,882.72	3,318.39	5,777.44	11,925.92	4,397.81	27,437.85	91,559.51	54,999.04	1,853.31	14,688.85	727,892.78	
Pennsylvania	410,041.76	18,201.04	1,234.76	2,175.68	6,663.72	5,617.96	30,861.48	126,341.18	27,633.20			628,770.78	59,211.45
Puerto Rico	312,885.43	9,063.61	2,873.07	1,686.44	8,548.90	2,691.69	1,379.48	50,604.83	18,647.32	53.85		408,434.62	55,120.42
Rhode Island	48,709.21	2,291.74	394.76		637.54	93.19	596.67	12,718.94	2,237.17			67,679.22	35,904.48
South Carolina	330,751.47	11,961.47	6,577.34	3,182.28	6,927.88	1,776.99	36,776.24	227,903.34	68,973.49	66,255.63		761,086.13	53,108.62
South Dakota	73,026.40	5,927.67	470.45	185.98	308.28	1,800.16	4,071.24	66,799.51	6,040.11			158,629.80	12,498.15
Tennessee	141,192.53	2,448.66	1,145.57	1,303.37	2,191.84	3,063.84	21,573.46	69,627.96	31,652.34	3,362.93		277,562.50	
Texas	737,480.53	19,972.41	3,414.50	4,095.06	17,644.06	4,991.82	22,850.93	229,890.06	149,787.80	87,864.60	17,630.40	1,295,622.17	551,117.25
Utah	134,562.86	11,023.77	1,151.30	2,288.12	7,876.57	3,676.66	7,575.47	32,594.41	24,725.61	19,472.62		244,947.39	28,315.28
Vermont	15,583.82	625.66	243.18	91.64	641.17	422.76	4,417.58	2,621.49	3,466.65		304.09	28,418.04	8,468.31
Virginia	244,396.80	24,832.57	1,955.53	3,189.55	8,416.80	4,673.80	8,218.62	40,185.77	41,337.10	5,618.65		382,825.19	44,259.81
Washington	475,283.77	28,347.91	5,192.29	4,369.18	7,850.69	3,673.27	16,835.34	163,183.68	57,013.94	48,848.22	5,031.00	815,629.29	
West Virginia	103,893.01	4,384.62	807.90	706.20	4,379.61	1,426.91	6,013.27	60,351.88	19,268.73	7,743.62		208,975.75	54,345.12
Wisconsin	1,011,579.00	24,932.00	3,645.00	2,044.00	6,931.00	6,347.00	51,698.00	268,749.00	19,362.00			1,395,287.00	
Wyoming	88,250.95	3,971.56	1,523.90	1,351.39	3,495.53	236.88	3,561.18	50,889.68	21,296.24	823.57		175,400.88	66,633.89
Total	16,988,525.62	727,522.31	124,349.09	164,650.26	403,872.76	313,311.61	871,067.44	5,033,005.53	1,950,143.05	1,075,791.51	47,760.05	27,699,999.22	6,176,098.38

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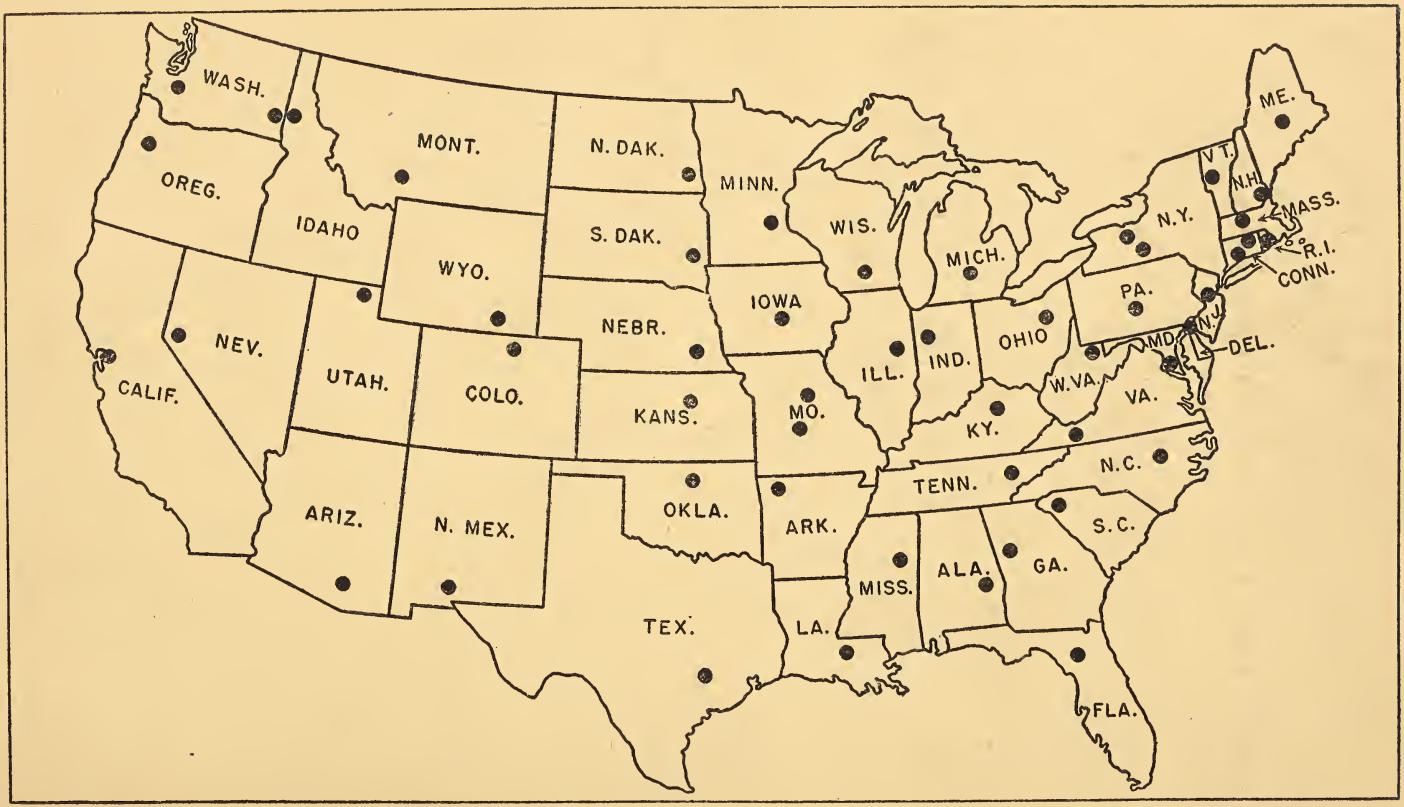
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